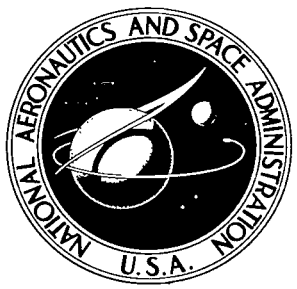
NASA TECHNICAL TRANSLATION

NASA TT F-523



NASA TT F-523

LOAN COPY: RETURN TO
AFWL (WLIL-2)
KIRTLAND AFB, N MEX

ELECTROMEDICAL APPARATUS; PRINCIPLES OF OPERATION, INSTALLATION, AND USE

by N. M. Liventsev

"Meditsina" Press, Moscow, 1964

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • MAY 1969

TECH LIBRARY KAFB, NM
0068953
NASA TT F-523

ELECTROMEDICAL APPARATUS; PRINCIPLES OF OPERATION, INSTALLATION, AND USE

By N. M. Liventsev

Translation of "Elektromeditsinskaya apparatura; printsip deystviya, ustroystvo, ekspluatatsiya." "Meditsina" Press, Moscow, 1964

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

For sale by the Clearinghouse for Federal Scientific and Technical Information
Springfield, Virginia 22151 – CFSTI price $3.00

TABLE OF CONTENTS

PREFACE TO THE THIRD EDITION.....vi

INTRODUCTION.....vii

CHAPTER I. PHOTOTHERAPEUTIC APPARATUS.....1

PART 1. OPTICAL RADIATION USED FOR THERAPEUTIC PURPOSES.....1
PART 2. LAMPS FOR INFRARED AND PHOTOTHERMAL RADIATION.....5
§1. Infrared Lamps.....5
§2. Lamps for Photothermal Radiation.....6
PART 3. LAMP FOR ULTRAVIOLET RADIATION.....8
§1. Argon-Mercury-Quartz Heater.....8
§2. Stationary Lamp for Local Ultraviolet Irradiation.....12
§3. Lamp for Local Ultraviolet Irradiation (Table Model)...16
§4. Lamp for Ultraviolet Irradiation of the Nasopharynx....19
§5. Powerful Lamp for Group Ultraviolet Irradiation.....21
§6. Lamp for Shortwave Ultraviolet Radiation.....25
§7. Bactericidal Lamps.....29
§8. Sunlamps.....32

CHAPTER II. ELECTROCARDIOGRAPHS.....34

PART 1. PHYSICAL PRINCIPLES AND METHODS OF RECORDING BIOPOTENTIALS.....34
PART 2. LOW-FREQUENCY AMPLIFIER.....38
PART 3. BATTERY-POWERED PORTABLE ELECTROCARDIOGRAPHS.....45
§1. Electrocardiographs EkP-4 and EkP-5.....45
§2. EkP-60 Electrocardiograph.....46
PART 4. ELECTROCARDIOGRAPHS POWERED BY LINE VOLTAGE.....57
§1. Electrocardiographs with Photorecording.....57
§2. Phonoelectrocardiograph.....72
§3. Electrocardiograph, Single-Channel, with Ink Recording.....79
§4. Two-Channel Electrocardiograph with Ink Recording.....90
§5. Vectorelectrocardioscopes.....100
§6. Multichannel Electrocardiographs.....110

CHAPTER III. DIRECT-CURRENT AND LOW-FREQUENCY ELECTROTHERAPEUTIC APPARATUS....113

PART 1. GENERAL CLASSIFICATION OF ELECTROTHERAPEUTIC METHODS AND DEVICES....113
PART 2. APPARATUS FOR DIRECT-CURRENT THERAPY....118
§1. Physical Principles and Methods of Applying Galvanization and Ionogalvanization....118
§2. Apparatus for Local Galvanization and Ionogalvanization....125
§3. Apparatus for General Galvanization, with Baths for the Extremities....130
PART 3. APPARATUS FOR DIAGNOSIS AND THERAPY, USING PULSED CURRENT....134
§1. Electrodiagnostics and Electrical Stimulation....134
§2. Vacuum-Tube Apparatus for Producing Pulsed Current....140
§3. Apparatus for Classical Electrodiagnostics....146
§4. Apparatus for Studying Electrical Excitability; Electrical Pulse Generator EI-1....152
§5. Apparatus for Electrical Stimulation of Muscles (ASM-3)....160
§6. Apparatus for Therapy by Sinusoidal Pulses; SNIM-1....169
§7. Apparatus for Electronarcosis....182
PART 4. THERAPEUTIC APPARATUS USING CONSTANT ELECTRICAL FIELD AND ATMOSPHERIC IONS....187
§1. General Considerations....187
§2. Franklinization and Atmospheric Ionization....190
§3. AF-2 Apparatus for Franklinization....192
§4. Apparatus for Franklinization and Atmospheric Ionization, AF-3....198
§5. Apparatus for Atmospheric Ionization Therapy and Atmospheric Ionization Prophylaxis....204

CHAPTER IV. ELECTROTHERAPEUTIC APPARATUS USING HIGH-FREQUENCY CURRENTS....209

PART 1. PHYSICAL PRINCIPLES AND METHODOLOGY OF HIGH-FREQUENCY THERAPY....209
§1. General Considerations....209
§2. Therapeutic Diathermy....213
§3. Surgical Diathermy....216
§4. D'arsonvalization....217
§5. Inductothermy....220
§6. Therapy Using an UHF Electrical Field....224
§7. Therapy Using a UHF Pulsed Electric Field....228
§8. Microwave Therapy....229
PART 2. GENERATOR OF ELECTRICAL OSCILLATIONS....231
§1. Oscillator Circuit....231
§2. Vacuum-Tube Generator....233
§3. Stabilization of Frequency and Suppression of Radio Interference....242

PART 3. APPARATUS FOR DIATHERMY.....252
§1. Universal Apparatus for Diathermy (UDL-350).....252
§2. UDL-350M Apparatus.....270
§3. Universal Diathermy Apparatus UDL-200.....273
§4. UDL-200M Apparatus.....285
§5. Apparatus for Surgical Diathermy EN-57.....288
PART 4. APPARATUS FOR D'ARSONVALIZATION.....295
PART 5. APPARATUS FOR INDUCTOTHERMY.....298
§1. Apparatus for Inductothermy, DKV-1.....298
§2. Apparatus for Inductothermy, DKV-2.....313
PART 6. APPARATUS FOR THERAPY USING A UHF ELECTRICAL FIELD IN A CONSTANT REGIME.....325
§1. Portable Apparatus for UHF Therapy UVCh-62.....325
§2. Apparatus for UHF Therapy, UVCh-4, Operating at a Power of 80 Watts.....330
§3. Apparatus for UHF Therapy, with a Power of 300 Watts (UVCh-300).....337
PART 7. THERAPEUTIC APPARATUS USING A PULSED UHF ELECTRICAL FIELD.....347
PART 8. APPARATUS FOR MICROWAVE THERAPY.....360
§1. Magnetron Generator.....360
§2. Apparatus for Microwave Therapy (Stationary Model "LUCh-58").....369
§3. Apparatus for Microwave Therapy (Portable Model "LUCh-2").....375

CHAPTER V. APPARATUS FOR ULTRASONIC THERAPY.....383

PART 1. PHYSICAL BASES AND METHODS FOR CARRYING OUT THE PROCEDURES OF ULTRASONIC THERAPY.....383
PART 2. APPARATUS FOR ULTRASONIC THERAPY.....387
§1. Apparatus for Ultrasonic Therapy (Portable Model UTP-1).....387
§2. Portable Apparatus for Ultrasonic Therapy (UTS-1).....395
§3. Instrument for Measuring Ultrasonic Power (IMU-2).....403

CHAPTER VI. ORGANIZATION AND OPERATION OF ELECTRICAL PHOTOTHERAPEUTIC DEPARTMENTS.....405

PART 1. ORGANIZATION OF AN ELECTRICAL PHOTOTHERAPEUTIC DEPARTMENT.....405
PART 2. ACCIDENT PREVENTION AND WORK RULES IN ELECTRIC PHOTOTHERAPEUTIC DEPARTMENTS.....407
PART 3. MAINTENANCE AND REPAIR OF APPARATUS.....413

****

PREFACE TO THE THIRD EDITION

The Third Edition has been expanded by a description of a number of new devices, designed and produced by the industry during the period which has elapsed since the preceding (Second) Edition went to press. The chapter on electrocardiograms has been nearly completely revised, having been expanded to cover the instruments currently being produced which operate on alternating current and use both photoelectric and ink recording. The chapter dealing with instruments for electrical stimulation has been expanded to include a device for treatment by alternating UHF (SNIM-1). The chapter on devices for UHF therapy has been expanded to cover the portable "UVCh-62" instrument, as well as the "Impuls-2" instrument for pulse-type UHF therapy. The chapter on instruments for microwave therapy has been expanded to include a description of the "LUCh-2" instrument. The chapter on apparatus for ultrasonic therapy has been nearly completely revised to cover both portable and fixed instruments of domestic manufacture.

The descriptions of the "UVCh-62" (Chapter IV, Part, 6 § 1), "Impuls-2" (Chapter IV, Part 7, § 1), "Luch-2" (Chapter IV, Part 8, § 2), and the ultrasonic devices UTP-1 and UTS-1 (Chapter V, § 2, 3 and 4) were written by the Director of the High-Frequency Instrumentation Laboratory of VNIIMIO, A. R. Livenson, for which the author expresses his gratitude as well as for the general editing of the texts of the Second and Third Editions.

As in the preceding editions, this edition provides the schematic diagrams of the electrical circuits and the ratings of the instruments as provided by the factory manuals and the technical descriptions, retaining the same symbols used in those diagrams and specifications. The author expresses his gratitude to the Directors of the Union Factory of EMA, the Leningrad Factory "Red Guard", and the Sverdlovsk Factory of the EMA, for making it possible to acquire the necessary technical data on the apparatus.

INTRODUCTION

Extensive use is being made by modern medicine of methods of diagnosis, prophylaxis, and therapy of diseases, which require the use of special apparatus. In addition, a highly diverse assortment of technical devices, instruments, and apparatus are being used in medicine for auxiliary purposes. All of the technical devices which are used by medicine are frequently referred to as "medical technology". The most important area of medical technology, in terms of its function and the tremendous number of complex instruments which it involves, is the one which involves the use of electricity. The heading of electromedical apparatus is usually used to cover, first of all, the devices used for physical therapy, in the fields of photo- and electrotherapy, and in the second place, the various types of diagnostic apparatus which are based, e.g., on the methods of electrical irradiation of tissue (electrodiagnostics), or are used for recording biopotentials (electrocardiography, etc.).

The development of electromedical apparatus has kept pace with the general growth of electrical technology and radio technology. The development of electromedical apparatus began only in the middle of the Nineteenth Century, when the first artificial sources of electricity were made available to practitioners: the electrostatic machine, galvanic cells, and (somewhat later) the induction coil. These sources of electricity were used in the earliest methods of electrotherapy, which were franklinization (static shower), galvanization, and ionogalvanization and faradization, along with electrodiagnostics by the classical method. The artificial light sources used in these forms of phototherapy were usually arc lamps and later powerful heating lamps (the so-called sollux lamps). At the beginning of this century, phototherapy by means of the mercury-quartz lamp was introduced into practice and became the first method of high-frequency electrotherapy: d'arsonvalization, in which a Tesla spark coil was used as the generator of the vibrations. This early period also saw the development of the first types of instruments of recording the biopotentials of the heart (electrocardiograms) by means of the capillary electrometer and the string galvanometer.

The rapid devlopment of electrical technology and radio in the present century not only has added considerably to the apparatus mentioned above, but has seen the development of a number of new instruments which have made it possible to introduce into

medical practice, new effective physical methods of therapy and diagnostics of various diseases.

In the field of phototherapy, e.g., the argon-mercury-quartz lamp was invented, which serves as a powerful source of ultraviolet radiation; there are also lamps which provide ultraviolet radiation in certain regions of the spectrum, which serve as sources of infrared radiation, etc.

As the vacuum tube continued to be used more and more, basic /6
changes were made in the sources of static electricity and galvanic current. Instruments appeared which produced pulse-type current at various frequencies, durations, and pulse shapes. They served as the basis for development of new methods of electrical diagnostics and therapy of ailments involving the nervous and muscular systems.

The development of radio technology was accompanied by the appearance of a new field of applications for physical methods of therapy, electrotherapy by means of high-frequency currents. In addition to the general inductive effect on the organism with the use of the so-called general d'arsonvalization, high-frequency electromagnetic oscillations were used to produce a heating effect; this was the first method of electrically heating tissues located deep inside the organism, and was called diathermy. The apparatus used for these methods was developed on the basis of spark generators of electromagnetic oscillations. The vacuum-tube spark generators, which were soon surplanted in radio technology, were retained for use in electrotherapeutic apparatus until relatively recent times.

In conjunction with the further development of radio technology in the 1930's, a new method of working on the organism (based on the vacuum tube generator) was devised with the aid of an Ultra High-Frequency electrical field. The method proved to be most effective and saw wide application in practice. Somewhat later, a new method of exerting a thermal effect on tissues located deep inside the body was used, called electromagnetic induction, and this method was therefore named inductothermy (otherwise known as short-wave diathermy). Recently, the development of pulse-type high-frequency technology, as well as the technology of electromagnetic vibrations at very high frequencies has made it possible to develop two new methods of high-frequency therapy: treatment of the organism with a UHF electrical field operating in the pulsed mode, and microwave therapy, which involves treating the body with electromagnetic waves in the deci- and centimeter wavelengths.

Finally, the development of highly sophisticated ultrasonic generators, based on the technology of high-frequency oscillations and suitable for medical purposes, has made it possible to apply ultrasonic vibrations for therapeutic purposes.

The development of radio technology has been of crucial sig-

nificance for the development of instruments in the field of electrophysiological investigation, especially for the recording of biopotentials of the heart (electrocardiography). The use of vacuum-tube amplifiers has made it possible to build relatively simple instruments and to devise a method of electrocardiography suitable for very wide applications. The construction of sensitive multi-channel amplifiers has made it possible to record biopotentials from the brain, which are many times weaker (electroencephalography). Modern technology has made it possible to design complex highly sensitive multi-channel devices for recording various parameters of the activity of the respiratory, cardiovascular, and other systems of the body.

All of this complex electromedical apparatus is based on vacuum tubes. However, modern developments in the field of electronics are showing a definite trend toward the use of semiconductors instead of vacuum tubes. The use of semiconductors makes it possible to effect a considerable reduction in the external dimensions of electromedical instruments, to lengthen their service lives, make them more available for use under the most diverse conditions, often directly at the patient's bedside.

It should be pointed out that before the Revolution there was /7
no production of electromedical apparatus in our country whatsoever, and imported equipment was used exclusively. However, immediately after the end of the Civil War, work began in earnest to construct our own forms of electromedical apparatus and an industrial base for their production.

Valuable assistance in the development and building of new forms of electromedical apparatus was rendered to industry during this period by the scientific research institutes: the State Institute of Physiotherapy (Moscow), the State Institute of Roentgenology and Radiology (Moscow), the Institute of Physical Methods of Therapy imeni I. M. Sechenov (Sevastopol), the Leningrad Physiotherapeutic Institute, the Moscow Regional Institute of Physical Methods of Therapy (Khovrino), etc.

At the present time, the medical supplies industry in the USSR has a large number of factories for producing electromedical apparatus. In addition, a number of complex therapeutic and diagnostic instruments are being built by electrotechnical and radio technical industrial enterprises. The scientific research and design aspects of developing new forms of electromedical apparatus were combined into one organization in 1947. This is the VIIMIO (All-Union Scientific Research Institute for Medical Instrumentation and Equipment), which has an experimental plant. New types of electromedical apparatus are also developed in the special design bureau "Biofiztribor" in Leningrad. Considerable work in improving the present models and developing new types of electromedical apparatus is being done at the laboratories of the factories which construct these instruments: the Union Factory of the EMA, the "Red Guard" Factory, the Sverdlovsk Factory of EMA, etc.

These organizations continue to receive considerable assistance from the specialists and researchers in various institutions, particularly the Central Scientific Research Institute of Balneology and Physical Therapy, where this work is headed by corresponding member of the Academy of Medical Sciences of the USSR, Professor A. N. Obrosov.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

TECHNICAL TRANSLATION EVALUATION

Budget Bureau No. 104-R037
Approval Expires: Sept. 30, 1969

TO: THE USERS OF THIS TRANSLATION →

NASA TTF NO. 523

MAINTAINING THE QUALITY OF NASA TRANSLATIONS REQUIRES A CONTINUOUS EVALUATION PROGRAM. PLEASE COMPLETE AND MAIL THIS FORM TO AID IN THE EVALUATION OF THE USEFULNESS AND QUALITY OF THE TRANSLATING SERVICE.

THIS PUBLICATION *(Check one or more)*

- ☐ FURNISHED VALUABLE NEW DATA OR A NEW APPROACH TO RESEARCH.
- ☐ VERIFIED INFORMATION AVAILABLE FROM OTHER SOURCES.
- ☐ FURNISHED INTERESTING BACKGROUND INFORMATION.
- ☐ OTHER *(Explain)*: _____

FOLD LINE FOLD LINE

TRANSLATION TEXT *(Check one)*

- ☐ IS TECHNICALLY ACCURATE.
- ☐ IS SUFFICIENTLY ACCURATE FOR OUR PURPOSE.
- ☐ IS SATISFACTORY, BUT CONTAINS MINOR ERRORS.
- ☐ IS UNSATISFACTORY BECAUSE OF *(Check one or more)*:
  - ☐ POOR TERMINOLOGY.
  - ☐ NUMERICAL INACCURACIES.
  - ☐ INCOMPLETE TRANSLATION.
  - ☐ ILLEGIBLE SYMBOLS, TABULATIONS, OR CURVES.
  - ☐ OTHER *(Explain)*:

_____

FOLD LINE FOLD LINE

REMARKS

FROM

DATE

NOTE: REMOVE THIS SHEET FROM THE PUBLICATION, FOLD AS INDICATED, STAPLE OR TAPE, AND MAIL. NO POSTAGE NECESSARY.

NASA Form 1332 AUG 66

GPO 915-777

CUT ALONG THIS LINE

CUT ALONG THIS LINE

CHAPTER I

PHOTOTHERAPEUTIC APPARATUS

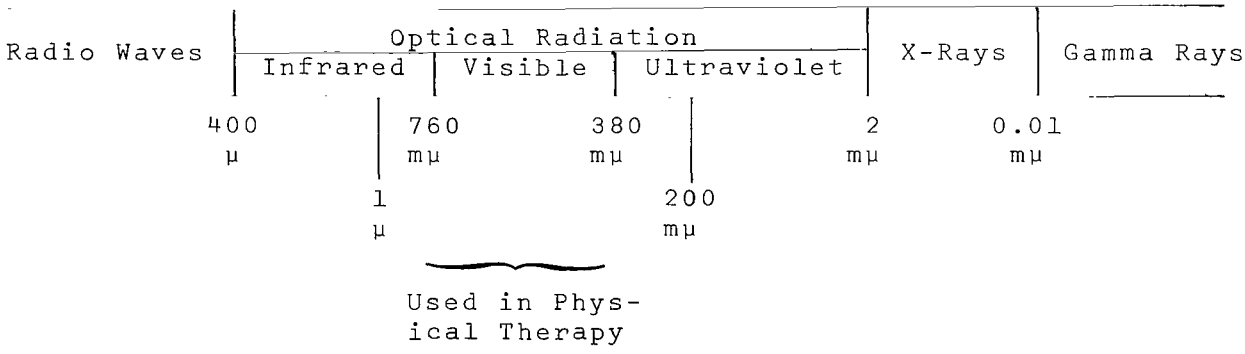
PART 1

OPTICAL RADIATION USED FOR THERAPEUTIC PURPOSES

Electromagnetic radiation in the wavelengths between 400 μ to 2 mμ is called optical. The optical radiation from 760 to 380 mμ, when it strikes the eye, creates the impression of light and is therefore called visible radiation. The optical radiation from 400 μ to 760 mμ is called infrared, and from 380 to 2 mμ is called ultraviolet. /9

The location of optical radiation in the total spectrum of electromagnetic waves is shown in Table 1.

TABLE 1



Physical therapy for prophylactic and therapeutic purposes uses infrared radiation at the extreme shortwave end of the spectrum (with wavelengths from 1 μ to 760 mμ, approximately), visible radiation, and ultraviolet radiation from 380 to 200 mμ. The ultraviolet radiation at these wavelengths is divided into three regions, according to the most characteristic biological effect:

1. Zone A, called antirachitic, from 380 to 315 mμ. It is

distinguished by a tonic and reenforcing effect on the organism, corresponding to the solar ultraviolet radiation reaching the Earth's surface. It is used primarily for prophylactic purposes.

2. Zone B, called eryth emic, from 315 to 280 mμ. It is characterized by an erythremic effect (see below), which is most pronounced at a wavelength of 297 mμ. It is used primarily for therapeutic purposes.

3. Zone C, called bactericidal, from 280-200 mμ. It is characterized by a bactericidal effect which is most pronounced at a wavelength of 254 mμ. It is used primarily as a means of disinfection.

Ultraviolet radiation has the ability to penetrate to a relatively shallow depth into the tissue of an organism; it passes only through the outermost layer of the skin. Infrared and visible radiation penetrate further into the tissue. /10

Optical radiation has a thermal and chemical effect. Both effects are characteristic of the entire radiation range, but to different degrees: infrared radiation exerts primarily a thermal effect, while ultraviolet radiation is mainly chemical in its action.

In the living organism, the thermal and chemical action of the radiation cause a complex biological reaction, whose external evidence is a reddening of the skin, called erythema. There are two phases in the action of the radiation: a hidden (latent) and open phase. During the latent phase, a number of phenomena occur in the organism which prepare it for the appearance of erythema. When erythema occurs, the second (open) phase begins.

Erythema corresponds to the occurrence of an inflammatory process in the skin (more exactly, in the entire organism). The degree to which erythema occurs in man depends on the nature of the radiation by which it is produced. In the case of rather intense action of infrared radiation on the irradiated portion of the skin, after several minutes one can see a mild, uneven reddening, which persists for a few minutes after irradiation is terminated and then vanishes nearly without a trace. Irradiation of the skin with visible radiation also causes relatively unstable erythema. Erythema of the latter type is called thermal erythema.

In the case of a more intense action of ultraviolet radiation, especially its longwave portion, the latent period increases significantly and lasts from 6 to 12 hrs, after which time a clearly bounded area of redness appears on the irradiated portion of the skin, accompanied by a sensation of pruritus and burning. The redness lasts for several days and then gradually fades away and vanishes, leaving behind a light brown pigmentation (tan). Repeated exposure causes the pigmentation to become more intense and to be retained for a longer period of time. In the case of extremely strong inten-

sity of radiation, burning of the skin can appear, with formation of blisters.

Infrared and ultraviolet radiation, when they strike the retina of the eye, do not produce a sensation of burning but have a significant effect (especially the ultraviolet light) on the surface membrane of the eye, the conjunctiva. This causes a very painful inflammation of this region (conjunctivitis). Therefore, both the patient undergoing radiation treatment and the personnel administering it must wear protective goggles which absorb the radiation.

The action of optical radiation of one type or another upon the organism is called irradiation. Irradiation is used to treat certain parts of the surface of the skin (adjacent parts which are not to be irradiated are then covered with a cloth which is opaque to the radiation) and certain mucous membranes of body cavities, which are responsive to the effects of radiation, such as the nasopharynx. Irradiation of this kind is called local. General irradiation (particularly in heliotherapy or prophylactic ultraviolet irradiation) are also used when the entire area of the body which is responsive to the rays is to be treated.

In any case, it is extremely important to maintain a strict measurement of dosage, i.e., measurement and limitation of the total amount of energy from the radiation striking the object during treatment. It is true that the biological influence of radiation depends on the energy of the radiation absorbed by the object. However, due to the difficulty of measuring the amount of energy absorbed by an object, the dosage is usually measured on the basis of the amount of energy striking the object, regardless of the fact that /11 part of the radiation is reflected from the surface. Dosage is determined by means of special devices called dosimeters.

Dosimeters for solar radiation are called actinometers and are based on measurement of the thermal effect of radiation. Thermoelectric phenomena are used in the most popular types of actinometers. Photoelectric cells are used as the basis for the design of most dosimeters for ultraviolet radiation.

Under practical conditions, if the intensity of the radiation from a given source is known or determined in advance by means of a suitable device, the radiation can be measured during the treatment itself. In doing this, it is necessary to keep in mind that the intensity of the radiation striking a given surface depends on the distance of this surface from the source (and also on the angle at which the radiation strikes the object, but this of less practical significance). If for the sake of simplicity we consider the source of radiation to be a point, we can say that the intensity of radiation striking a given surface (with all other conditions being equal) is inversely proportional to the square of the distance from the source to the surface. For example, if this distance is increased by one and a half times, the intensity of the radia-

tion will decrease by 1.5^2, or 2.25 times. Therefore, it is standard practice in carrying out radiation treatment to check both the duration of the treatment and the distance between the source of the radiation and the surface being irradiated. This distance is usually set at about 50 cm.

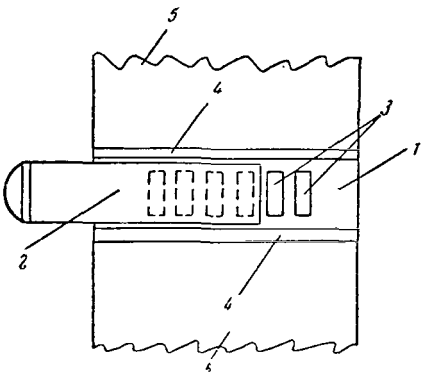


Fig. 1. Biodosimeter.

One shortcoming of this method of dosimetry is the fact that the intensity of the radiation from a given source decreases in the course of time, so that the duration of the exposure must be increased correspondingly. In shifting from a worn out source to a new one, the duration of the exposure must be sharply reduced.

In order for the ultraviolet exposure to be controlled as a factor of both the actual intensity of the radiation and the photosensitivity of the skin, a means of determining the so-called biodose has been devised. The biodose is defined as the duration of exposure to radiation which is required to produce in a given individual under certain conditions, a definite occurrence of erythema. The biodose is determined for the surface of the organism at the most photosensitive area of the skin at a distance of 50 cm from the lamp. To determine the biodose, a special device called the Gorbachev biodosimeter is used. This device (Fig. 1) consists of a metal (or plastic) strip 1, which is opaque to ultraviolet rays and in which 5 or 6 rectangular openings 3, measuring 5 × 15 mm have been made. These holes are located 5 or 6 mm apart. Guides 4 are mounted transversely to the length of the strip, along which a second strip 2 can be moved to uncover the openings one by one. The device is held in place on the body by means of a belt 5.

To determine the biodose, the apparatus is placed on the corresponding portion of the body, after which the entire surrounding area of skin is shielded from the effect of the ultraviolet rays. The openings in the biodosimeter are then opened one after /12
the other, so that each subsequent opening is revealed (or, on the other hand, covered up) after one minute. This means that the skin below the corresponding openings is exposed for 1, 2, 3, 4, 5 and 6 minutes. After 15-20 hrs, the erythema produced is examined. The minimum exposure required to produce noticeable erythema is used as the biodose for that patient. In all further therapeutic procedures, the exposure time to radiation is governed by the previously determined biodose. The average biodose for the most popular radiation source, the PRK-2 lamp, at a distance of 50 cm, is 2-3 minutes.

Sources of optical radiation can be divided into thermal and

luminescent types. In the thermal types, the radiation is produced by heating a physical body of some kind to a high temperature (carbon, metal, etc.). The primary source of thermal radiation is the Sun.

Artificial sources of thermal radiation are incandescent lamps, electric arcs, etc.

In luminescent sources, the radiation occurs in conjunction with certain other processes which do not involve heating, such as electrical discharges in gases. The mercury lamps (both high and low pressure) are the luminescent sources which see the widest application in medicine.

PART 2

LAMPS FOR INFRARED AND PHOTOTHERMAL RADIATION

§ 1. INFRARED LAMPS

The infrared lamp used for therapeutic purposes serves as a source of relatively shortwave infrared (invisible) radiation and visible red radiation close to this range. The source of the radiation is a heated element, consisting of a metal coil wound on a ceramic base. The coil is heated by electric current approximately to red heat (about 400°). Lamps used for infrared irradiation are produced in two versions: the stationary model (mounted on a stand) and the table model. Both lamps use a heating element with a power of 600 W and a coil which operates at a voltage of 127 or 220 V.

At the present time, only the portable lamp is being produced. This lamp is shown in schematic form in Figure 2, and consists of a metal polished reflector 4, in the middle of which is located a type Ts-27 socket, with a heating element 6. The reflector is mounted on an arm 3, which can be moved and rotated around a column 2, which has a tripod base 1, mounted on castors. In addition, the reflector can be tilted up to an angle of 90°. The dome of the reflector is fitted with a single-pole switch and is provided with ventilating openings. The heating element is shielded on the side facing the patient by a small screen 5.

The heating element consists of a metal coil, wound on a ceramic base which is conical in shape. The coil is made of Fecraloy or nichrome wire, 0.4-0.5 mm in diameter. The resistance of the coil when heated at a voltage of 127 V is 26 ohms and 80 ohms at a voltage of 220 V. The current consumption at 220 V is 2.7 A, and 5 A at 127 V.

In applying the treatment, the lamp is arranged so that the heating element is 60-70 cm distance from the surface being irradiated (the area of the irradiated surface is a circle 25-30 cm in diameter). The patient experiences a feeling of rather intense heat. /13

§ 2. LAMPS FOR PHOTOTHERMAL RADIATION

Heating lamps produce radiation which consists of a considerable amount of shortwave infrared, a small amount of visible, and a very small amount of longwave ultraviolet radiation. The latter is usually absorbed by the glass of the bulb. Radiation of this type is called photothermal. Photothermal radiation is provided by lamps called sollux lamps, and by photothermal baths.

The sollux lamp is a relatively powerful heating lamp, mounted in a special reflector. The name of the lamp ("sollux" in Latin means "sunlight") has been retained from former times when lamps were used for this purpose which employed a heating coil made of various special alloys, and it was felt that the spectrum of irradiation from such lamps was similar to sunlight. However, this was not actually the case.

The sollux lamp is produced in three versions: the stationary, portable, and table models. The power of the stationary lamp

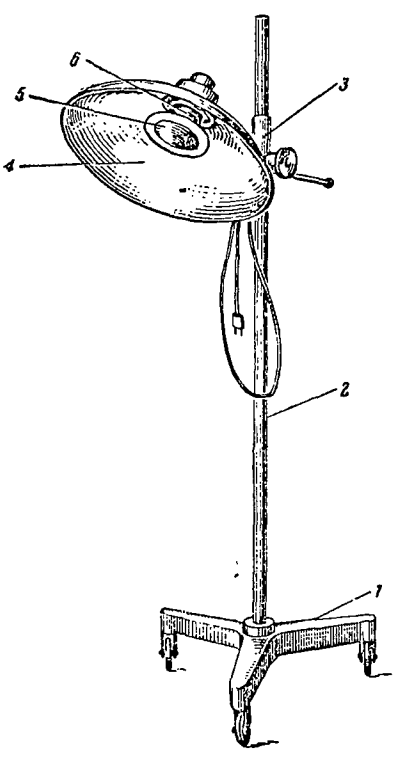


Fig. 2. Infrared Lamp on Stand.

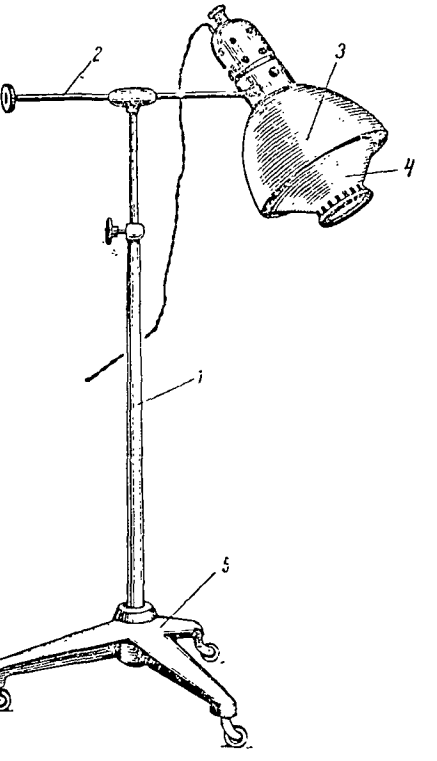


Fig. 3. Lamp for Photothermal Irradiation (Sollux), Mounted on Stand.

is 500 W. The lamp is built for use at a line voltage of 127 or 220 V. When operated on 127 V, the lamp must be connected to a special circuit and be provided with a separate switch. /14

Figure 3 shows a general view of a stationary sollux lamp. The lamp is mounted in a socket with a Ts-40 thread, and located in a large spherical reflector 3, which is attached to column 1 by means of an arm 2. The lamp is intended for irradiating large areas of the body. In order to irradiate smaller areas of the body, the lamp is fitted with a tubular nose 4, which is mounted on the reflector.

The portable sollux lamp is provided with a folding stand and can be carried in a case, while the table model is equipped with a special table stand. In both cases, the power of the lamp is 200 W. The lamps are intended for use at line voltages of 127 and 220 V, and can be plugged directly into the wall socket.

In using these lamps, it is important to see that the base of the lamp is firmly fastened to the base and the base is firmly screwed into the socket, since these parts of the lamp are occasionally overheated and may lose their required strength. In order to prevent the possibility of glass fragments falling on the patient if the glass envelope of the lamp should break during treatment, it is suggested that the lamp be placed somewhat to the side of the patient and that the reflector be set to the proper angle. When the treatment is over, the lamp must be disconnected at once.

The photothermal bath (Fig. 4) consists of a light semicylindrical case, with two halves 1 and 2 joined by hinges, which make it possible to close the case for transport. The outside of the case is provided with handles.

The inside of the case is fitted with brackets and sockets 3 for heating lamps 4 of conventional incandescent type, with a power of 40 W (or close to this value), operating on 127 or 220 V depending on the power supply available. The wiring to the sockets is led through the inside of the walls of the case. The heating lamps are connected in two different groups. On the front wall of the case is an outlet 5 for the power cord and a switch 6 which can be used to turn on the lamps either together or separately.

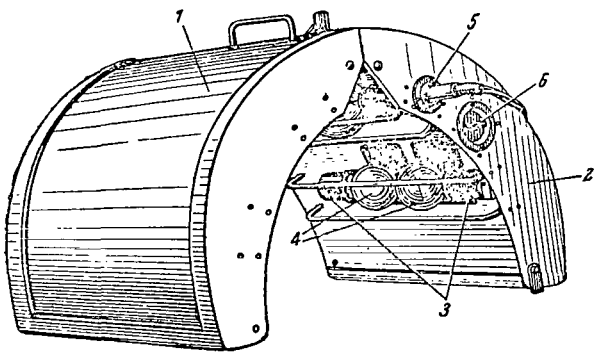


Fig. 4. Photothermal Bath.

Two types of photothermal baths are in production: a 12-lamp model for irradiating

the trunk and an 8-lamp model, smaller in size, for irradiating the extremities. The bath for the trunk has a power consumption of 480 W while the bath for the extremities consumes 320 W.

PART 3

LAMP FOR ULTRAVIOLET RADIATION

§ 1. ARGON-MERCURY-QUARTZ HEATER

At the present time, the principal source of ultraviolet radiation is the mercury lamp, in which an electrical discharge is passed through mercury vapor. Mercury lamps of both high and low pressure type are used in medicine, and differ in their light spectra. The high-pressure mercury lamp is called the argon-mercury-quartz lamp, or (in order to distinguish it from the apparatus as a whole) the argon-mercury-quartz heater. /15

The heater consists of a short tube made of quartz glass, sealed at the ends, from which the air has been exhausted and replaced by argon gas at low pressure. The tube also contains a small quantity of mercury. Metal electrodes are fused into the ends of the tube, and covered with alkaline-earth metal oxides to improve emission of the electrodes. Figure 5 shows two heaters: type PRK-2 (a) and PRK-4 (b), which are currently in production. The numbers on the figure are as follows: (1) central working portion of the heater; (2 and 5) fittings for mounting the heater in the reflector; (3) terminal lugs; (4) electrodes; (6) so-called capacitor strip.

The heater operates as follows. When a voltage source is connected to the electrodes of the heater, a charge builds up in the argon gas with which the tube is filled. The ionization of the gas is caused by the single ions which are always present in a rarefied gas. Under the influence of the electrical field, these ions move between the electrodes and acquire a certain velocity, striking

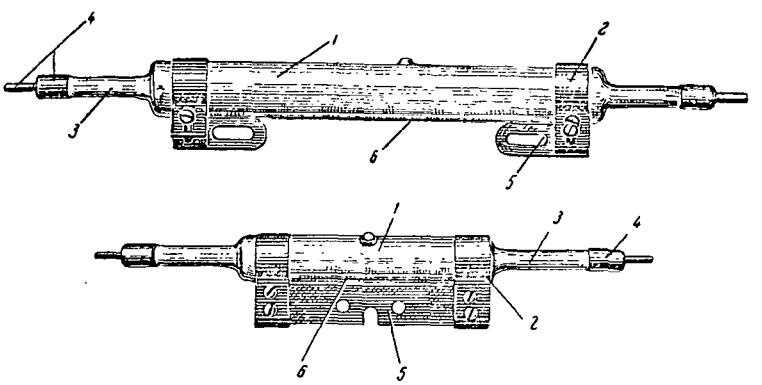


Fig. 5. Argon-Mercury-Quartz Heaters PRK-2 and PRK-4.

the atoms of the gas and ionizing them on impact. The ionization of the gas gradually intensifies and a glow discharge appears between the electrodes. This causes the electrodes to heat up due to their bombardment by gas ions and the phenomenon of electron emission from their surfaces. The entire heater warms up and the mercury which it contains is vaporized. An arc discharge then is produced in the mercury vapor. The vapor pressure increases to a certain level and is maintained during the normal operating cycle of the heater.

Hence, the principal operating cycle of the heater is the arc discharge in mercury vapor. Filling the heater with argon merely facilitates its ignition. The ignition of the heater is also facilitated by a narrow metal strip (called the capacitor strip), which /16 is attached to the external surface of the heater. This strip acts like a capacitor plate, with the wall of the heater tube acting as the dielectric and the ionized gaseous medium located inside the tube being the second plate. The capacitor plate is connected to one of the heater electrodes by a low-value capacitor (see Fig. 5). When the voltage supply is attached to the heater, charges appear on the capacitor strip; according to the law of electrostatic induction, this causes the appearance of charges with opposite sign in the gaseous medium within the heater. This increases the degree of ionization of the gas and facilitates the production of a charge in it.

At the moment when the heater is ignited and the gas discharge is formed, its electrical resistance decreases sharply and the current intensity increases. To limit the starting current, as well as to stabilize the current during the operating cycle, a choke or rheostat is connected in series in the heater circuit. This causes the voltage across the heater to drop to 30-40 V upon ignition. This regime lasts from 2 to 4 minutes. When the arc discharge is formed and the mercury vapor pressure increases gradually, the current intensity in the heater circuit drops to 3-4 A, while the voltage across the heater increases to 115-120 V. These data apply to the so-called starting cycle of heater operation.

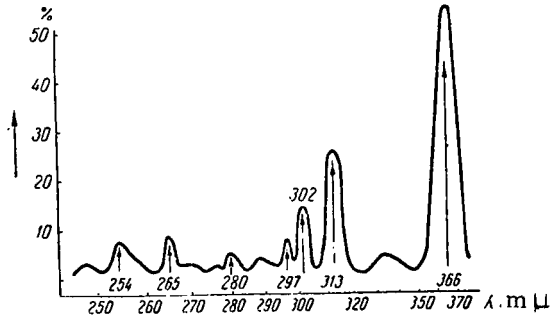


Fig. 6. Energy Distribution in the PRK Heater Spectrum.

Heating up of the heater and establishment of the operating cycle usually requires up to 12-15 minutes. Before being ignited for a second time, a heater which has been extinguished must be allowed to cool completely, and 8-10 minutes are required.

After a prolonged use of the heater, its radiation inten-

sity decreases, particularly in the ultraviolet portion. This process is called aging of the heater. This also causes its external appearance to change: the quartz glass is covered on the inside by a deposit and becomes less transparent.

The radiation from the argon-mercury-quartz heater has a linear spectrum and consists approximately of 45-50% visible radiation, primarily in the blue-violet portion of the spectrum, and 50-55% ultraviolet. The latter belongs primarily to Zones A and B. The most intense radiation in the ultraviolet portion of the spectrum is found at 365 and 313 mμ.

Figure 6 shows the graph of energy distribution (expressed in percent of the total radiated power) for the wavelength in the spectrum of the PRK type heater.

The data on the operating cycle of the PRK heater are given in Table 2.

Type PRK-2 and PRK-4 heaters are used in stationary and portable lamps. Type PRK-7 is used in lamps for group irradiation. Type PRK-2 heaters are used in lamps at a working voltage of 220 V, while the PRK-4 heaters operate at 127 V. When the PRK-2 heaters are powered by 110-127 V, they must be connected to a step-up autotransformer.

The schematic diagram for connecting the heater to a source of alternating current, as recommended by the factory which manufactures the heater, is shown in Figure 7. Heater 1 is connected to the voltage source, with a choke 5 connected in series with it. /17 The capacitor strip is connected to one of the power leads through a capacitor 2 with a capacitance of 300-500 μμF, of low-loss type (mica). In some types of lamps, the capacitor strip is connected directly without this capacitor to one of the heater electrodes.

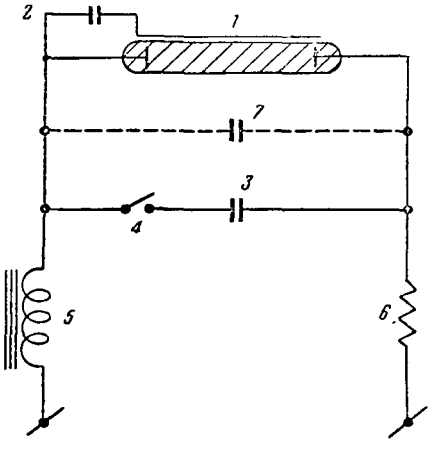


Fig. 7. Schematic Diagram of Circuit for Argon-Mercury-Quartz Heater.

In the diagram, a dashed line is used to represent the connection of capacitor 7 to the electrodes; the purpose of this capacitor is to reduce radio interference which is caused by the operation of the heater. The capacitor must be adequate to withstand a breakdown voltage of 1500 V, and has a value of 0.005 μF for PRK-4 heaters and 0.005-0.007 μF for heaters of all other types. Since the lamps which are currently produced do not generate radio interference which exceeds permissible levels, capacitor 7 is usually omitted.

The diagram also shows an additional circuit, connected in parallel with the heater electrodes, consisting of a spring-loaded button 4 and a capacitor 3 with a value of 2-3μF with a working voltage of 300-600 V. This circuit is used to facilitate ignition of the heater under certain conditions, e.g., when there is insufficient voltage in the circuit or the heaters are old, etc. If the button is pressed after connecting the heater to the circuit, capacitor 3 and choke 5 form a ferro-resonance circuit. When this circuit is interrupted, as happens when the button is released, a pulse of increased voltage appears across the heater, thus facilitating its ignition. The newer types of heaters usually ignite easily as soon as they are connected to the line. However, as the tubes age, it becomes increasingly difficult to ignite them. Therefore, provision is made in the power circuit for many lamps to provide this additional circuit to facilitate ignition.

The factory recommends that when the choke has a low active resistance, a small resistor 6 should be connected in series with the heater; the value of this resistor (6-11 ohms) is selected to ensure proper operation of the heater.

Table 3 shows the characteristics of chokes for various heaters, as recommended by the factory.

TABLE 2

Lamp type	Line voltage	max. starting current in A	max. duration of transient operation in min.	characteristics during constant operation		
				current in A	voltage in V	power in W
PRK-2	220	6	15	3,75±0,25	120±6	375±13
PRK-4	127	5	10	3,75±0,3	70±5	220±3
PRK-5	220	4,2	15	2,3±0,15	120±6	240±11
PRK-7	220	14	10	3,05±0,5	135±6	1000±40

TABLE 3 /18

Lamp	operating cycle		starting cycle	
	voltage in choke in V	current in A	voltage in choke in V	current in A
PRK-2	170	3,75	220	5—6
PRK-4	87	3,75	127	1,5—5,0
PRK-5	163	2,3	220	3,1—4,2
PRK-7	151	8,05	220	11,7—14,0

The following excerpts from the operating instructions for the type PRK heaters are worth mentioning:

1. The normal operating position of the heater is horizontal, with tilting 15° in either direction being permissible.

Use of the heater in the vertical position (or close to it) is permissible only when provision is made for additional cooling of the upper reflector, which otherwise will overheat and shorten the operating life of the heater.

2. It is recommended that the outside of the heater be cleaned daily with a cloth moistened with alcohol. This prevents the formation of deposits from grease spots which may be on the heater and undergo combustion. In general, when handling the heater, it should be grasped only by the metal bracket, since fingers leave greasy spots on the quartz.

3. When using the heater in a closed space, provision must be made for suitable ventilation to prevent the heater from becoming too hot.

4. When installing the heater in the reflector, care must be taken to ensure that the capacitor strip is located on the side of the heater which is turned toward the reflector.

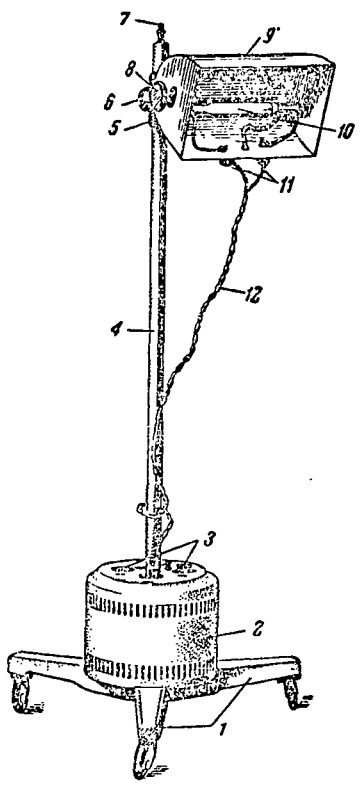


Fig. 8. Stationary Lamp for Local Ultraviolet Irradiation.

§ 2. STATIONARY LAMP FOR LOCAL ULTRAVIOLET IRRADIATION

The stationary lamp for local ultraviolet irradiation, using a type PRK-2 heater, is produced by several factories. An overall view of the lamp in one of its earlier versions is shown in Figure 8. The lamp has a heavy tripod base 1, equipped with castors. In the center of the base, there is a hollow vertical nickel plated column 4, to which an arm, carrying parabolic reflector 9 and heater 10, is attached by a sleeve 5. The reflector is mounted on the semiaxes of the arm, so that it can rotate around the horizontal axis and be fastened in the desired position by means of clamping screw 8. Sleeve 5 is fixed to the column by means of a clamping screw 6. To facilitate moving sleeve 5 along the column, a counter weight is located inside the latter and connected to the sleeve by a steel cable. The cable runs through a pulley 7, fastened in a

bushing, which is freely mounted at the upper end of the column.

The heater is fastened by screws to a support located inside /19
the reflector and connected to terminals 11 (located on the lower edge of the reflector) by flexible cables insulated by glass beads. Cable 12, which runs from the power supply of the lamp, is connected to these terminals. In some versions of the lamp (in particular, in the lamp shown in Fig. 8) the reflector has a third terminal mounted in the center and connected to the reflector housing. A flexible cable insulated by glass beads is connected to this terminal and links it to the capacitor plate on the heater. Between this terminal and one of the power terminals, a capacitor is connected which is then in the capacitor plate circuit. The third terminal has been omitted from lamps of more recent manufacture.

The capacitor for facilitating ignition of the heater is missing from the electrical circuitry of the lamp. The heater usually ignites when the supply of voltage is fed to it. If the heater has been used for a long time and does not ignite when connected, it is possible to use a separate capacitor with a value to 2-3 μF (at a working voltage of 400-600 V). Two insulated leads, 20-30 cm long are soldered to the terminals of the capacitor. To facilitate ignition of the heater, after the supply voltage has been connected to it, the tips of the wires soldered to the capacitor are touched several times to the heater lugs or terminals to which the supply voltage is connected.

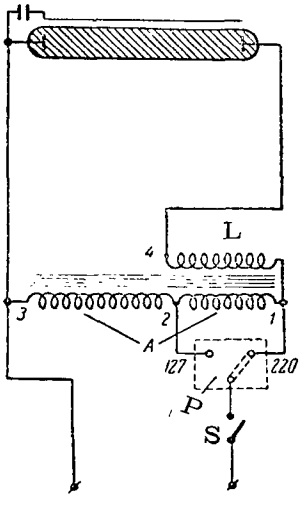


Fig. 9. Schematic Diagram of Stationary Lamp for Ultraviolet Irradiation, for Use at Line Voltages of 127/220 V.

A cylindrical housing 2 mounted on the base of the stand contains the apparatus for powering the heater. The lamp is produced in two versions, one for use at a line voltage of 220 V and the other for use at either 127 or 220 V.

In the lamps for use at 220 V, only a choke and switch are connected in series in the heater line.

In the lamps for use at 127 or 220 V, the power section contains an autotransformer which steps up the line voltage from 127 to 220 V, which then reaches the heater through the same choke as is used for lamps designed to be used at 220 V (at line voltages of 220 V, the autotransformer operates without any load). The schematic diagram of the power section of lamps of this kind is shown in Figure 9. The autotransformer and choke are made in a single unit, as shown in Figure 10. Winding A of the autotransformer, located at the lower end of the core, contains a total of 676 turns

(286 turns between terminals 1 and 2 in the diagram shown in Figure 9 and 390 between terminals 2 and 3). The wire used is type PEL, with a diameter of 1.35 mm. At the upper end of the core, where the air gap is located, the choke coil L has been wound. The coil (terminals 1-4) has 480 turns of PBD wire, 1.56 mm in diameter. The entire air gap in the choke winding is occupied by pressboard packing and amounts to about 4 mm. The gap is set carefully during assembly for the operating cycle of the heater.

A terminal strip P is mounted on the frame on which the choke- /20 autotransformer is wound; it is used to connect the lamp to 127 or 220 V, and is provided with a circuit switch S.

The cover of the housing at the lamp base has openings 3 (Fig. 9) through which the power leads and the lead to the heater run, as well as the switch knob and the grounding terminal.

The weight of the lamp including the choke-autotransformer is 25 kg.

The power consumption of the lamp is a function of the power consumption of the heater plus the power required for the operation of the power supply itself. The nominal power of the PRK-2 heater is given above in Table 3. The power consumption of individual heaters can vary from the nominal value to a significant degree. On the average, the lamp draws a current of 5.1 A when operating on 127 V, which corresponds to a total power of 650 W. When the lamp is operated on 220 V at a current of 4.0 A, this corresponds to a power of 880 W. The active power consumption in both cases amounts to approximately 450 W.

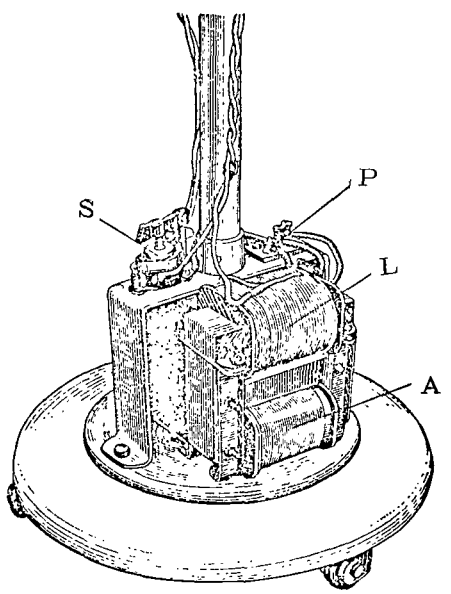


Fig. 10. Choke-Autotransformer Assembly Used as Power Supply for PRK-2 Heater at 127/220 V.

At the present time, the Sverdlovsk factory of the EMA is manufacturing a stationary lamp of new design, with the designation "irradiator, mercury-quartz, on stand". An overall view of the lamp is shown in Figure 11. It has a tripod base on castors, with the power supply contained in a housing 1. The top of the housing is fitted with a switch 11 and pushbutton 12. In the center of the base, there is a vertical column 2. A light arm can be moved along the column by means of a sleeve 3; a reflector 6 with heater 9 is mounted on the semiaxes of the arm. Sleeve 3 is held automatically in firm contact with the column by means of a

tension spring located inside the sleeve. To move the sleeve along the column, it is necessary to overcome the resistance of the spring by turning handle 4 on the arm around the axis to some angle, up to the stop. This frees the spring and the sleeve can be moved easily along the column.

The reflector is cylindrical in shape and can be rotated on the semiaxes of the arm by means of a handle 8, after which it can be fastened firmly in place by means of a clamping screw 5. The heater is held in the reflector by two spring clips 7.

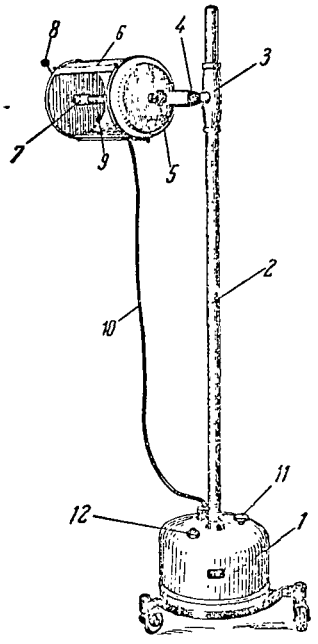


Fig. 11. Mercury-Quartz Lamp on Stand.

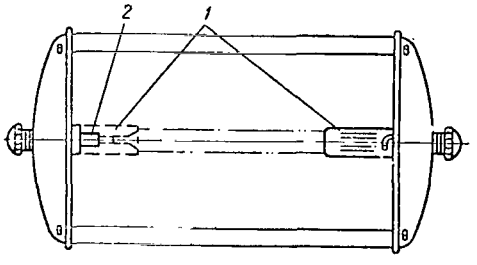


Fig. 12. Fittings for Holding Heater in Lamp.

To install the PRK-2 heater in the reflector, it is necessary to remove the fittings with which it is supplied (see the point marked 5 in Fig. 6). The protective covers 1 can then be removed from the reflector of the lamp (Fig. 12) and placed over the ends of the heater with the openings to the sides.

Then, by pressing on the spring-loaded fittings 2 (one with the end of the heater and the other with a finger of the free hand), the heater can be inserted between them. Finally, the covers 1 are replaced and turned on the pivots to match the openings.

The wires which power the heater pass through the double walls of the reflector and are connected to the spring contacts 2. These wires connect the current-carrying contacts with the terminals in a socket, located on the lower surface of the reflector. A three-prong plug is inserted in the socket, and is in turn connected to a three-conductor cable 10 which runs to the power supply (the third wire is for grounding the reflector). /21

The overall dimensions of the lamp are as follows: height of the top of the column from the floor, 1700 mm; distance of the axis of the reflector from the axis of the column, 505 mm; weight

of the lamp (for use on 127 V) 28.2 kg.

The lamps are manufactured on a mass production basis for use with 220 or 127 V power supplies. The schematic diagram of the power supply for these lamps is shown in Figure 13. For use on 220 V (Fig. 13a), choke 5 is included in the heater circuit 1 (in the lamps previously manufactured, a small resistor was also included in series), as well as a capacitor 3 with button 4 for ignition, a line switch 6 and connecting terminals 2 in the reflector. In the lamp for use on 127 V (Fig. 13b), the circuit for the heater 1 contains an autotransformer 7 in addition to the choke. The circuits are identical in all other respects. Line switch 6 is designed as a unit. The terminal strip for connecting the line voltage of 127 or 220 V to the lamp is located inside the housing 1 (Fig. 11).

The lamp is connected to the line voltage by means of a three-conductor cable (the third wire is for grounding).

The technical data for the power supply of this lamp are as follows: choke - cross sectional area of the core 15 cm^2 with an air gap of 3-5 mm; winding - 457 turns of PBD wire, 1.56 mm in diameter; autotransformer - core cross section 18.4 cm^2; winding: 286 turns of PEL wire, 1.5 mm in diameter and 320 turns of PEL wire, 1.35 mm in diameter. The resistance in the heater circuit is 2 ohms. The ignition capacitor has a value of 2 μF at a voltage of 400 V. The filter capacitor for reducing radio interference has a value of 6800 pF at a voltage at 1500 V.

The method of performing general or local ultraviolet irradiation is as follows: the surface of the body which is to be irradiated is exposed, and the lamp is placed somewhat to the side in order to preclude the possibility of any pieces of the lamp falling on the patient in the event that it should break during the treatment. The distance of the area being irradiated from the heater must be measured carefully according to the instructions, with a measuring tape being used when setting up the lamp. The radiation is measured as a function of the exposure time at a given distance from the heater, which is established on the basis of a previously /22 determined photosensitivity of the patient, i.e., his biodose.

When carrying out the treatment, or whenever working in the phototherapeutic laboratory, it is necessary to observe certain rules for protection against radiation. The rules are given below in the corresponding section. In general, it calls for protecting the eyes of both the patient and the personnel from the effects of radiation by means of special dark goggles.

§ 3. LAMP FOR LOCAL ULTRAVIOLET IRRADIATION (TABLE MODEL)

In 1953, the VNIIMIO developed a table lamp for local ultraviolet irradiation, which has been produced for about two years

by the Sverdlovsk factory of the EMA as type LKN-II (lamp LKN-II was described in the preceding edition of this book which appeared in 1950). Since then, the factory has improved it and now is producing a new design under the designation "lamp, mercury-quartz, table model". The lamp is intended for use with the PRK-4 heater at voltages of 220 or 127 V.

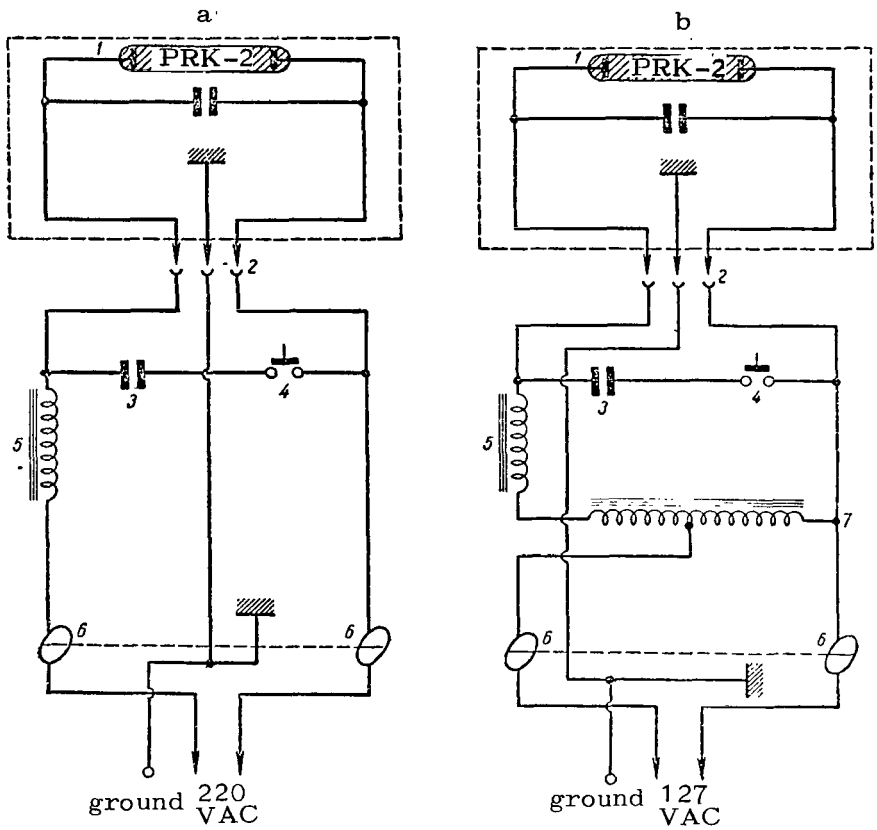


Fig. 13. Schematic Diagrams of Lamps. (a) For Use on 220 V; (b) For Use on 127 V.

According to the ratings, the operating voltage of the PRK-4 heater is 120 V (see Table 3). Therefore, the heater can be connected either to a 220 or 127 V line (through a choke). However, experience has shown that when the PRK-4 is connected to a power line with a nominal voltage of 127 V, it ignites poorly, especially when the voltage in the line falls below the nominal value. Hence, in order to facitate ignition of the heater when using the lamp on 127 V, a combined choke-autotransformer is incorporated in it. /23

The schematic diagram of the lamp is shown in Figure 14. Heater 3 is connected in series in the line with choke 4, which consists

of two coils K_1H_1 and K_2H_2, a selector switch 5 for selecting either 127 or 220 V, and switch 6. In addition, the circuit also contains capacitor 1 and spring loaded button 2, which form the system for igniting the heater.

When the lamp is being operated on 220 V, two choke coils are connected into the circuit in series with the heater.

When the lamp is operated on 127 V, only one coil (H_1K_1) of the choke is connected into the circuit with the heater. The other coil (H_2K_2) can be connected by pressing button 2 to ignite the heater; it is then connected in series with capacitor 1 to the power source to form a ferro-resonant circuit, parallel to the heater circuit. When the button is released, the circuit is interrupted and the voltage surge ignites the heater.

The following are data on the power supply for the lamp: choke wound on an inverted-L-shaped core with a cross sectional area of 9 cm^2 and an air gap of 4.0-4.2 mm. The winding is made of PEL wire, 1.3 mm in diameter. Coil H_2K_2 consists of 270 turns, while coil H_1K_1 consists of 402 turns. Capacitor 1 is of MKV type, 2 μF, with a working voltage of 500 V.

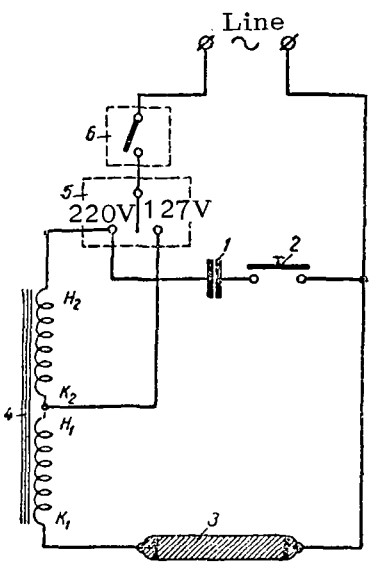


Fig. 14. Schematic Diagram of Mercury-Quartz Lamp (Table Model).

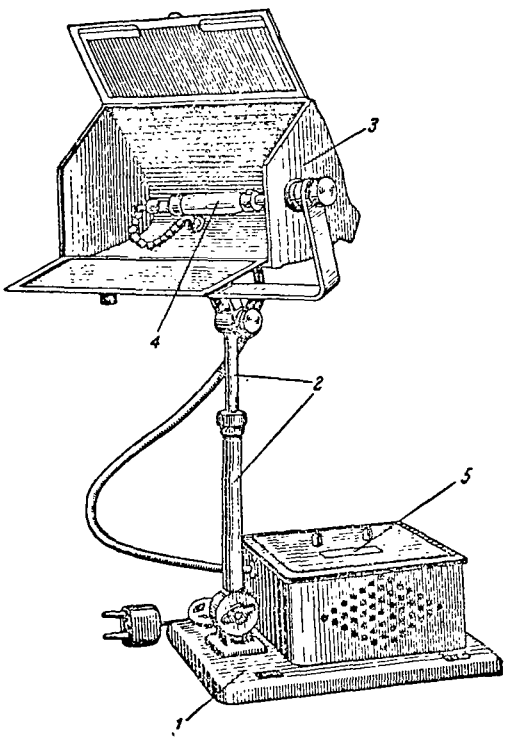


Fig. 15. Mercury-Quartz Lamp (Table Model).

When operating on either 127 or 220 V, the lamp consumes approximately 4 A, which corresponds to a full power of 500 volt-amperes at 127 V and 850 volt-amperes at 220 V. The active power consumption in both cases is about 300 W. /24

Figure 15 is a general view of the lamp. The power supply 5 is mounted on the base 1 in a common unit; column 2, carrying reflector 3 and lamp 4, has a telescoping feature. The lamp is covered by a housing which is not shown in the figure. The overall dimensions of the lamp in its housing are 385 × 260 × 185 mm. Its weight is 9 kg.

The following are several remarks regarding procedure. When preparing the lamp for operation, it is necessary to remove the housing, check the heater mounting and be sure that the wires leading to the heater are not in contact with the reflector. The selector switch for voltage is then set to the proper position. Check to be sure that the power switch is in the off position. Then close the doors on the reflector and set the reflector in the required position with respect to the patient. The power cord can then be plugged directly into the wall socket.

Turn on the power switch; if the heater does not ignite, push the button. After 3-5 minutes, when the heater cycle has become established, the lamp must be set in its final position with respect to the area to be irradiated, after which the doors of the reflector are opened.

When treatment is complete, it is not necessary to shut off the heater but merely to close the doors on the reflector. The heater can be re-ignited only after it has cooled completely.

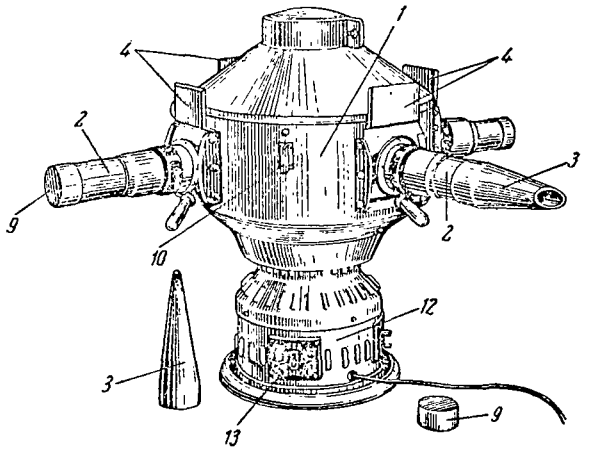


Fig. 16. Overall View of Nasopharyngeal Irradiator.

The average biodose for lamps of this type corresponds to an irradiation lasting 2-4 minutes at a distance of 50 cm from the heater.

§ 4. LAMP FOR ULTRAVIOLET IRRADIATION OF THE NASOPHARYNX

One of the most widespread methods of combating grippe and its complications is the ultraviolet irradiation of the tonsils. This irradiation is accomplished by means of a tube directed into the open mouth of the patient. The State Institute of Physiotherapy has developed a spe-

cial lamp for irradiating the nasopharynx in four patients simultaneously.

An overall view of the lamp developed by the Sverdlovsk factory of the EMA under the designation "nasopharyngeal irradiator", is shown in Figure 16. Figure 17 shows schematically the internal parts of this lamp (the numbers in the pictures are the same). The lamp consists of a circular housing 1, fitted with four tubes 2, located mutually perpendicular in the horizontal plane. The tubes are fitted with removable tips 3 (tubes through which radiation is not being given are covered by caps 9). The heater 7 (type PRK-4) is mounted vertically in the middle of the housing on a support 6. To ensure a normal temperature range, the upper end of the heater is fitted with an aluminum radiator 8.

The length of the tube with its tip ensures that the distance /25
from the heater to the irradiated surface is 50 cm. To facilitate setting up when carrying out the treatment, the middle portion of the tube is fitted with a telescopic device, while the base of the tube can be rotated through a small angle in the vertical plane. Each tube is fitted with a mirror 4 and a handle 5, which can be used to aim the opening of the tube at the object being irradiated.

The base 12 contains the power supply, which is completely similar to the power supply of the table model lamp (see Fig. 14). Panel 13 is equipped with a power switch, ignition button, and selector switch for 127 or 220 V. The lamp is plugged into the wall socket by means of a line cord with a plug 14.

The overall dimensions of the lamp are as follows: height,

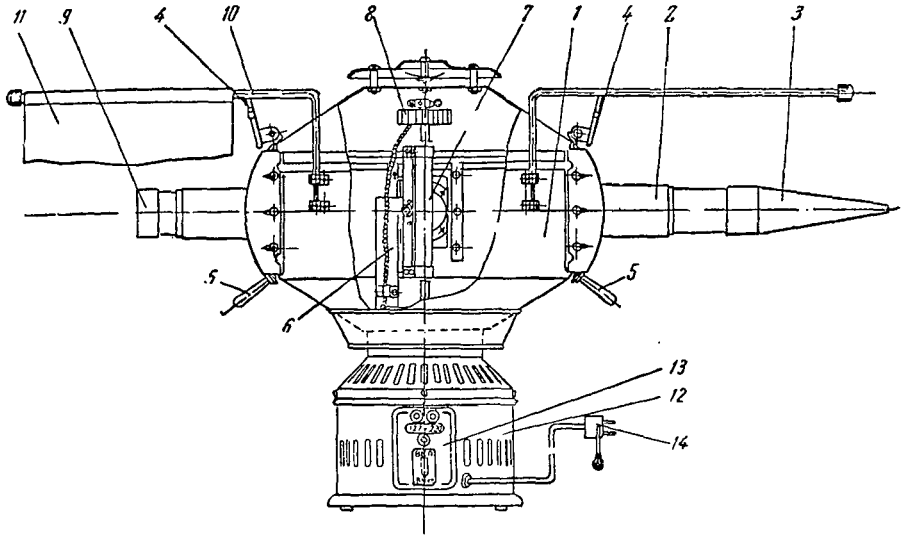


Fig. 17. Diagram of Nasopharyngeal Irradiator.

505 mm; length of the tubes without tips, 325 mm; with tips, 520 mm. The weight of the lamp is 11 kg.

The lamp is placed on a circular table, around which the patients are seated on stools which can be adjusted vertically by screwing them up or down and which are fitted with soft headrests. Between the tubes, curtains 11 are suspended from arms 10 to separate the patients from one another (in Fig. 16, the arms are not shown).

§ 5. POWERFUL LAMP FOR GROUP ULTRAVIOLET IRRADIATION

The lamp consists of a powerful source of ultraviolet rays, used for simultaneous irradiation of a group of patients for prophylactic or therapeutic purposes.

Prophylactic ultraviolet irradiation is used widely in pediatrics, as well as in schools and physical culture, as well as for persons who do not receive sufficient sunlight owing to the nature of their work (e.g., persons working underground, etc.).

The procedure for prophylactic irradiation with this powerful lamp is shown schematically in Figure 18. The persons undergoing treatment, fitted with protective goggles, stand in a circle at a certain distance from the heater and turn around in place slowly during the irradiation process, first in one direction then in the /26

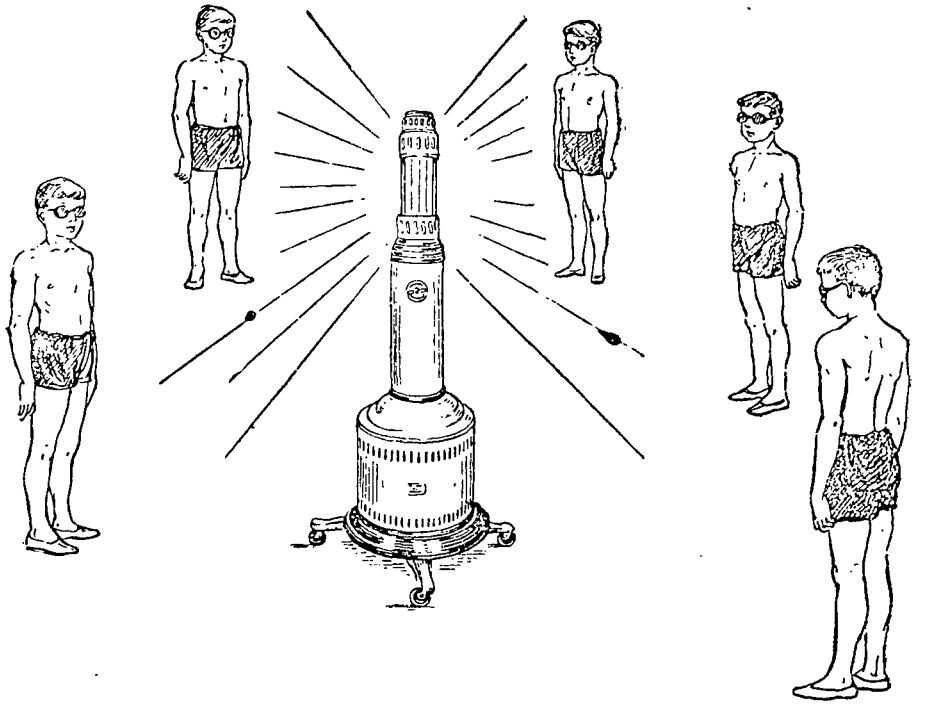


Fig. 18. Group Ultraviolet Irradiation.

other. The figure shows a lamp of earlier design, which was described in detail in the Second Edition of this book (1960). At the present time, the Sverdslovsk factory of the EMA is producing two types of lamps for group irradiation: "lamp, omnidirectional, large" and "lamp, omnidirectional, small" for the irradiation of children.

The large omnidirectional irradiator (Fig. 19) consists of a cast iron base 1 with three legs fitted with castors, a case 2 in which the power supply is located, a movable support 3, and a head 4 with heater 5. The heater can be covered by a special protective cap. On top of the power supply housing are the handle 6 for the power supply, button 7 for igniting the heater, and a fuse beneath a protective cover 8. The adjustable support makes it possible to set the heater at any level from 1050 ± 20 to 1340 ± 20 mm.

The lamp is connected to the power supply by means of a three-conductor cable (the third wire serves for grounding), which comes out through the lower part of the cap 2. The length of the cable is 5 m.

The electrical circuit of the lamp consists of the heater (type PRK-7) intended for use with 220 V and consisting (Fig. 20a) of a switch 3, choke 4, fuse 2, capacitor 7, ignition button 8, and heater 1, with capacitors 5 in the capacitor-strip circuit and 6 for reducing interference. (Fuse 2 is included to protect the circuit from the constant component of the current, which occurs in some heaters in conjunction with the rectifying effect produced by the temperature differential of the electrodes).

In order to operate the device on 127 V, the factory (upon request from the customer) will equip the lamp with an autotransformer 9, which must be connected as shown in Figure 20b. The autotransformer has leads for connecting it to line voltages of 110 /27
or 120 V.

The following are data on the power supply of the lamp. The choke has a core cross section of 20 cm^2, with an air gap of 2-4 mm, a winding of 280 turns of PBD wire 2.44 mm in diameter. The instrument is fitted with a 15 A fuse. The capacitors are as follows: in the ignition circuit, 2 μF at 400 V, in the heater circuit, 470 pF, and for reducing interference, 6800 pF at 1500 V.

The autotransformer has the following features: cross sectional area of the core, 25 cm^2, number of windings -400 (PBD wire 2.3 mm in diameter); the latter consists of two coils of 200 turns each with taps at 100 and 116 turns in each.

The irradiator is mounted in the center of a special room, where the irradiation is carried out ("photarium"), measuring no less than 6 × 7 m. This ensures that there will be sufficiently uniform radiation (with an error of ± 15%) at the level of the

heater, at a distance from the latter of at least 2 m. Up to 20 persons can be irradiated at once. The average biodose at a distance of 2 m is 3-4 minutes.

The power supply should preferably be located below the floor or at least in a closed well in the floor. On the wall in a different part of the room, near the nurse's post, the instrument panel is mounted. This panel is fitted with a control switch and 50 A fuses for operating at 120 V (or 25 A for operating at 220 V). It is important to ensure that the proper current in amperes is drawn by the irradiator (see Table 4).

TABLE 4.

	voltage	
	220	127
starting cycle	14	26—28
operating cycle	7—8	14—16

The active power consumed by the heater is 1000-1200 W.

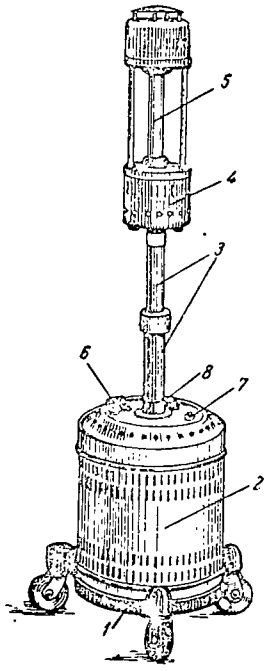


Fig. 19. Large Omnidirectional Irradiator.

To perform the treatment, the switch on the panel is first turned to the on position, after which the switch on the irradiator is turned on. If the heater does not ignite at this point, the pushbutton is depressed several times. The person who is igniting the lamp must shield his eyes by means of goggles and move away from the lamp immediately as soon as it is lit.

Eight to ten minutes after ignition, irradiation can begin. The irradiator is designed for constant operation, but it is recommended that a rest period of one hour be provided after every six hours of continuous operation. the heater can be switched on again only after it has cooled completely, for which 15-20 minutes are required.

Before ignition, it is suggested that the heater be wiped with a rag moistened in clean alcohol. The heater should not be switched on until the alcohol is evaporated completely.

If the voltage is turned on and the heater does not ignite, a voltmeter must be used to measure the voltage at the terminals. /28

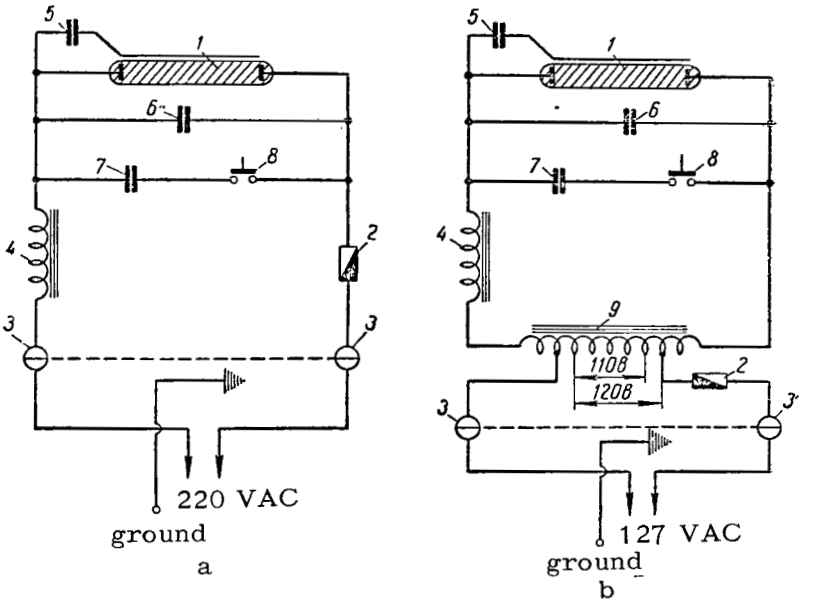


Fig. 20. Schematic Diagram of Large Omnidirectional Irradiator. (a) Operation at 127 V; (b) Operation at 220 V.

If none is found, it may be assumed that the fuse has blown, that the contacts of the switch are damaged, or that the wires are broken. In order to locate these breakdowns, it is necessary to remove the cover from the base of the irradiator and check to see whether the fuse and other parts are intact. The fuse should not be replaced by a higher amperage substitute.

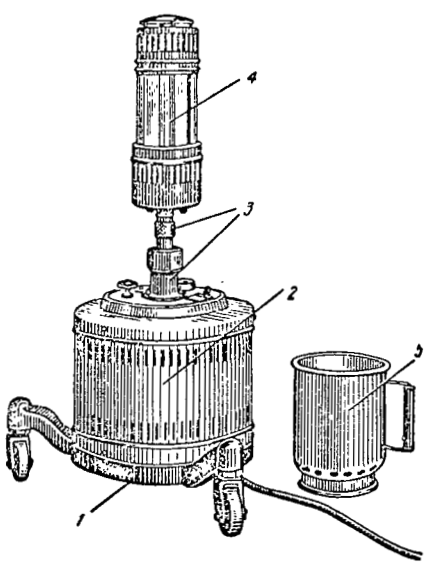


Fig. 21. Small Omnidirectional Irradiator.

If the heater flashes on ignition and then goes out, it indicates that the line voltage is insufficient (test with voltmeter). If the line voltage drops 10% below its normal value, the heater may operate unstably; in these cases, it is necessary to use a separate autotransformer.

When the irradiator is not being used, it must be covered with a hood. It is recommended that the housing of the irradiator be opened no less than once a month and a vacuum cleaner used to remove dust which has accumulated on the parts inside. The external surface of the housing can be cleaned in the usual way with conventional liquid disinfectants.

The small omnidirectional irradiator resembles the large ir- /29
radiator in its design (in recent models, the parts have largely been the same). However, it uses the PRK-2 heater, so that its electrical system corresponds to that of the "irradiator on stand" (see § 2). It also is manufactured for use with 200 or 127 V line voltage. The irradiator (Fig. 21) consists of a base 1, adjustable stand 3, head 4 with heater and power supply 2, mounted on base 1 in housing 2. The top of the cabinet contains the following: handle for power switch, ignition button, and fuse under protective housing. The irradiator has a power cord 5 m long, which is connected to the lower part of the power supply along with the grounding wire. Figure 21 shows the protective cap 5 next to the irradiator; this cap is used to cover the heater during the periods before and after treatment. The head of the irradiator is fitted with slots to hold filters of uviol glass to reduce the spectral content of the radiation (the filters are not produced by the factory).

The adjustable stand makes it possible to set the heater at any level from 820 to 1100 mm.

The irradiator produces uniform radiation (with an error of ± 15%) on the level of the heater, beginning at a distance of 0.8 m from the lamp. Up to ten people can be irradiated simultaneously.

§ 6. LAMP FOR SHORTWAVE ULTRAVIOLET RADIATION

In 1954, the VNIIMIO developed a lamp for shortwave ultraviolet radiation, based on the principle of the excitation of a glow discharge in a conventional mercury-quartz heater by subjecting the latter to an ultrahigh frequency voltage. The high frequency electrical field thus formed inside the heater ionizes the argon gas inside much more intensely, so that a glow discharge appears in it. Then the merccury, which is also located in the heater, is vaporized; however, due to the low temperature of the heater, the pressure of the mercury vapor remains low and its operating cycle resembles that of a low pressure mercury lamp. In this case, it is also possible to use old heaters in which the arc discharge is not formed owing to loss of emission at the electrodes.

The lamp which is produced by the Union factory of EMA under the Model No. LKUF-3 consists of the PRK-4 heater, operating in a glow discharge cycle, produced by electromagnetic oscillations at ultrahigh frequency to power the heater. Under these conditions, the PRK-4 heater delivers primarily (up to 85%) shortwave radiation with a wavelength of 254 mμ. Intensity of the radiation is low, so that the lamp is intended for use in local irradiation of /30
small areas of skin and mucous membranes. The average biodose for this type of irradiation is usually given at a distance of 20 cm for a period of 3-4 minutes.

The design of the lamp is shown in Figure 22. The heater is located in a small trough-shaped reflector 1, covered with a hous-

ing, to which a tube 2 can be fitted. The reflector, heater, and tube are mounted on a hinged support 3, which permits the tube to be directed at any angle required for treatment. The UHF generator used to power the heater is mounted in a metal suitcase, fitted with a compartment in the back for storing the support section and the reflector. The parts of the generator are mounted on the back of the instrument panel 4 and can be lifted out along with it. The external dimensions of the suitcase are 150 × 280 × 310 mm. The weight of the lamp is about 10 kg.

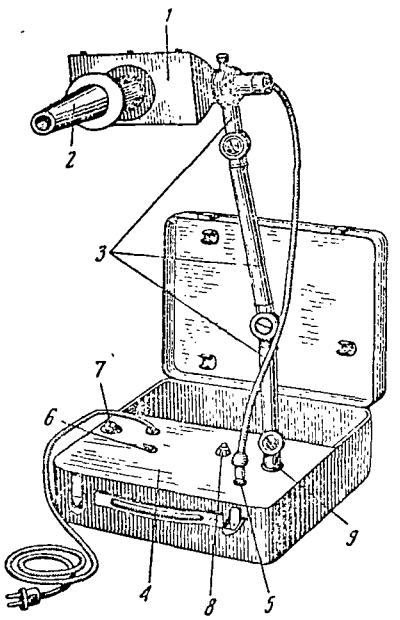


Fig. 22. Lamp for Short-wave Ultraviolet Radiation (LKUF-3).

The lamp is plugged directly into the wall socket and can be used either on 127 or 220 V.

The instrument panel is equipped with the following: at the left, power switch 6 and the fuse, along with the voltage selector switch 7 and the opening for the power cord; on the right are the lens 8 of the signal lamp, socket 9 to receive the support pin and socket 5 for the wire running to the heater. The wire in the circuit is shielded, with the shielding grounded to the chassis; the latter is fitted with a terminal for grounding. The lamp must be grounded.

Figure 23 shows the schematic diagram of the lamp. The generator which powers the heater operates at a frequency of 40.68 MHz $\pm$ 2% (the lamp which was produced until 1964 had an operating frequency of 39 $\pm$ 1 MHz). The generator consists of a 6P3 tube (shown as V_2 in the diagram), operated as a triode. The operating principle of the generator is described below in the section on high frequency apparatus. The parts of the oscillator section of the generator are as follows: input capacitance of cable K, capacitor C_8, inductance coil L and capacitor C_6.

Tube V_2 is included in this circuit because of the voltage which is formed across resistance R from the constant component of the circuit current. A choke L_2 is connected in series with resistor R, while the resistor is shunted by capacitor C_7. Heater H is connected in the anode circuit of the generator by a section of high frequency cable K. The second lead of the heater is connected to the reflector and runs to the chassis through the cable shielding. The chassis of the apparatus is grounded. /31

The generator is powered by a rectifier consisting of a keno-

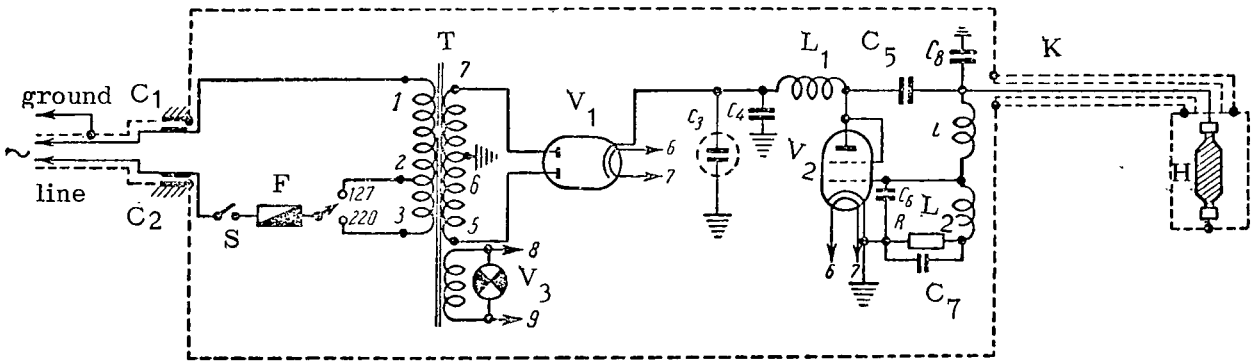


Fig. 23. Schematic Diagram of LKUF-3 Lamp.

Specifications for Schematic Diagram of LKUF-s Lamp

R	VS-1 Resistor, 10 KΩ ± 20%	K	High frequency cable RK-49
C_1, C_2	Capacitor KPB, 500 V, 0.025 μF ± 20%	H	Mercury-quartz heater, PRK-4
		V_1	Kenotron 6Ts5S
C_3	Capacitor KE-2, 450 V, 20 μF	V_2	6P3S tube
C_4, C_5, C_7	Capacitor KSO-5, 500 V, 65800 pF ± 20%	V_3	Pilot light, 6.3 V - 0.28 A
		T	Power transformer
C_6	Capacitor KTK-4, 250 V, 160 pF ± 20%	F	Fuse PK-45, 1 A
		S	Power switch
C_8	Capacitor KTK-1, 20 pF ± 10%		
L_1, L_2	High frequency choke		
L	Induction coil		

tron V_1, connected to the step-up winding of transformer T and filter capacitor C_3. A high frequency choke L_1 and a capacitor C_4 are connected as a unit in the circuit powering the lamp. A dividing capacitor C_5 is connected to the anode of the lamp.

The primary winding of the transformer is connected to the line by a switch S, a fuse F, and voltage selector for 127 or 220 V. To suppress radio interference which is transmitted through the wiring when the line cord is plugged in, filter capacitors C_1 and C_2 are included in the circuit.

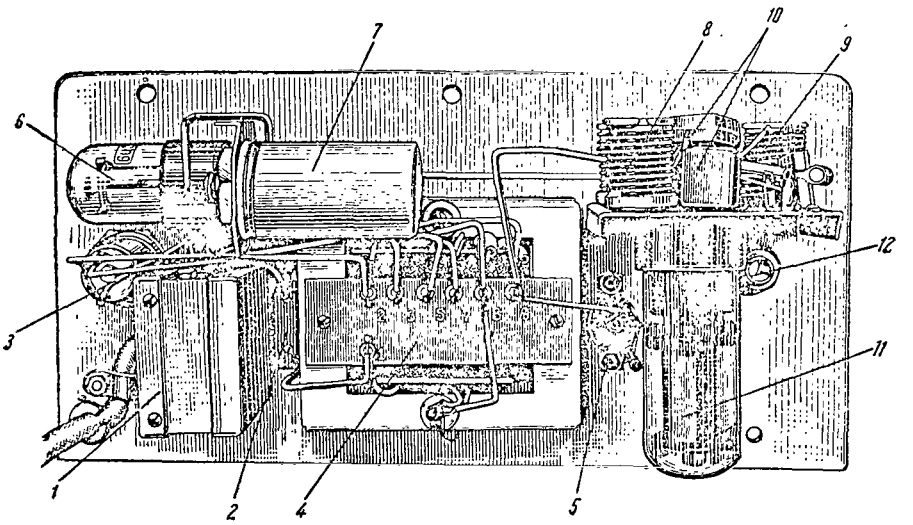


Fig. 24. Arrangement of Components in LKUF-3 Lamp.

Figure 24 shows the arrangement of the components on the back of the control panel in the power supply of the lamp. In the center, the transformer 4 is mounted to the right of capacitor 1 for the line filter, switch 2, and the fuse, as well as the voltage selector 3, kenotron 6, and filter condenser 7. To the right of the /32 transformer are the following: socket 5 for the pilot light, generator tube 11, and parts 8-10 of the oscillator system. Near the generator tube is socket 12 for the stand supporting the reflector.

The parts of the lamp, aside from the generator as a unit, the support rods with the reflector, and the PRK-4 heater with its high frequency cable, there are also tubes and nozzles (3), a reflecting shield (1), a tape measure (1) and goggles to protect the eyes from the radiation (2), as well as a spare 1 A fuse.

The procedure is as follows: the apparatus is mounted in the horizontal position and the lid is opened; the supports are set into the socket and the reflector is adjusted. The power cord is connected from the heater to the socket on the control panel, after which the reflector is tightened to the support by a clamping screw.

Ground the apparatus. Turn the fuse-voltage selector so that the arrow on it points to the proper voltage. After checking to be sure that the power switch is in the off position, the power cord can be plugged into a wall socket.

The portion of the body to be irradiated is then exposed and the reflector set at the proper distance for treatment; this distance can be measured from the axis of the heater to the surface of the body with a tape measure. The radiation can be performed with an open reflector. If the radiation is to be carried out with the tube, then an opening of the desired size is made by placing a nose over the tube on the reflector. Then the protective goggles are placed on the patient (the personnel carrying out the treatment must also wear protective goggles) and the switch on the control panel is thrown to the on position. After about 30 seconds, the operating cycle of the heater is established and the time of treatment can be measured from then on.

When the treatment is over, the apparatus is turned off, the plug is pulled out of the socket, the ground wire disconnected, and all the parts are packed in the suitcase. The tube which was used is sent off to be washed or sterilized.

§ 7. BACTERICIDAL LAMPS

The bactericidal lamp is a mercury lamp which operates at low pressure and produces shortwave ultraviolet radiation that has a bactericidal effect. The lamps are used for disinfecting air, the skin of the body, surgical supplies or instruments, etc. The principle of the design of the lamp is the use of a glow discharge produced in mercury vapor at low pressure (the vapor pressure of the mercury during the operation of the lamp amounts to 0.01 to 1 mm Hg.

The radiation from the lamp has a linear spectrum occupying the region of the ultraviolet from 254 mμ to the limit of the visible radiation in the blue-violet region (up to 577 mμ). Most of the radiation is at the 254 mμ wavelength and amounts to about 80% of the total flux.

At the present time three types of bactericidal lamps are being manufactured: PUV-15, PUV-30, and PUV-30P, which differ in power. The characteristics of these lamps are listed in Table 5.

The lamp (Fig. 25) consists of a narrow cylindrical tube 1 /33
made of uviol glass, which is highly transparent to shortwave ultraviolet radiation. This tube is filled with argon at a pressure of several mm Hg, and also contains a drop of mercury. At the ends of the tube are two electrodes 2, which act as heating coils. The electrodes are heated when igniting the lamp and their emissions (along with the ionization of the argon) facilitate the formation of a glow discharge in the mercury vapor. Choke 3 is connected

in series in the power supply to the lamp; a starter, or igniter, 4 is connected in parallel with the lamp.

TABLE 5

Lamp Type	Volt. in V	Nominal Power in W	Current in A	Dimensions of Lamp		
				Tube Length in mm	Overall Length in mm	Tube Dia. in mm
BUV-15	127	15	0.26-0.32	436.5	452.5	25
BUV-30	220	30	0.32-0.34	834	910	25
BUV-30P	127	30	0.5-0.6	437	452	25

A capacitor with a low capacitance is connected in parallel with the starter to reduce radio interference (the condenser is located inside the starter itself).

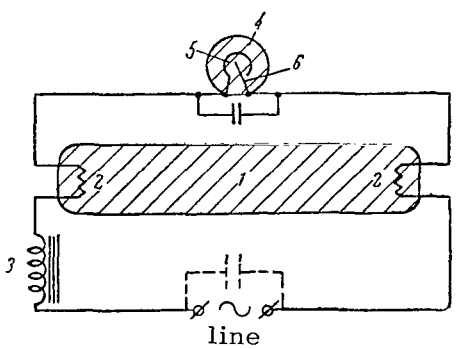


Fig. 25. Diagram of Design and Circuitry for Bactericidal Lamp.

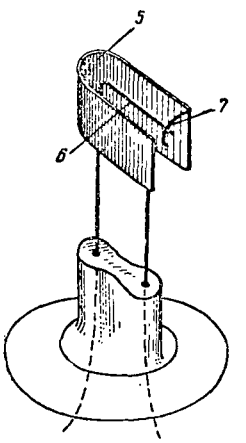


Fig. 26. Diagram of Construction of Electrodes in Igniter for Bactericidal Lamps.

The starter (Fig. 26 shows schematically only the design of the starter electrodes) is a neon lamp, whose electrode 6 is made of a bimetallic strip. To turn on the starter, it is connected to a voltage supply in series with the electrode coils of the lamp. This causes a glow discharge to occur between electrodes 5 and 6 of the starter, so that electrode 6 becomes heated and bends slightly to touch contact 7 on electrode 5. Electrodes 5 and 6 of the starter are shortened, while the electrode coils of the lamp are connected in series with the power supply and are therefore heated by the current passing through them. At this moment the bimetallic electrode cools off and the circuit to electrodes 5 and 6 of the starter is suddenly interrupted. The supply voltage is then applied to the heated electrodes of the lamp and an electrical discharge appears

in the latter. Ignition of the lamp is facilitated by the fact that at the moment when the electrodes of the starter open, there is a pulse of electromotive force in the circuit produced by self-induction in the choke. After several seconds, the operating cycle is established in the lamp.

Bactericidal lamps are used in special holders. Two types of holders are manufactured: wall-mounted and suspended (ceiling mount). The wall-mounted irradiator contains two lamps; the ceiling-mounted model, which is actually a pair of wall mounted units connected back to back, contains four lamps. The irradiator is intended for disinfecting air in operating rooms, dressing stations, maternity wards and contagious wards of hospitals, etc., as well as in locations where large numbers of children gather (schools, theaters, movie houses).

The suspended irradiator (Fig. 27) consists of a metal body 1, in which two compartments for lamps are provided on each side (in Fig. 27, only one side of the irradiator is visible). One of these openings is open, with a reflector 3, and the second 2 is located behind reflector 3; the radiation from the latter is directed only toward the ceiling. The lamp located in the open section is /34 used for rapid irradiation of an entire area, but it can only be used when there are no people present. The lamp located in the second compartment can be used even when persons are in the room, since it disinfects only the upper layers of air (the rest of the air is subjected to this treatment by the process of natural convection). There are additional pieces of equipment mounted inside the irradiator housing: chokes and starters. The suspended irradiator contains four lamps: two BUV-30 P in the open compartments and two BUV-15 lamps in the closed compartments. The irradiator is intended for the disinfection of air in a room measuring 45 m^3 and is suspended from the ceiling at a height of 2-2.3 m from the floor.

The wall-mounted irradiator consists of half a ceiling-mounted unit and contains two BUV-30 P lamps, with one in the open compartment and the other in the closed compartment. The wall-mounted irradiator is intended for disinfection of rooms measuring 30 m^3. When the exposed lamp is used, one hour is required for disinfection, while when the concealed lamp is used, eight hours of constant operation of the lamp are required to disinfect the room. The irradiator is fastened to the wall 2-2.3 m above the level of the floor.

The schematic diagram of the irradiator (Fig. 28 shows the circuit for the wall mounted unit) contains a corresponding number of parallel circuits which have individual switches. Starters 3 (type SK-127) are connected in parallel with lamps 2. Chokes 1 (type DBM 15-127) are connected in series with the lamps. The irradiators are intended for use with 127 V only (a separate autotransformer must be used when these lamps are to be used on 220 V). The irradiator operates at a power of 50-69 volt-amperes for each lamp.

Each lamp in the irradiator must have its own switch. The switch for the exposed lamp (or the group of exposed lamps if several irradiators are being used in the same room) must be located outside the room to be irradiated; it must also be fitted with a special warning light bearing the inscription "bactericidal lamp on". Personnel located in a room where the exposed lamps are burning must wear protective goggles.

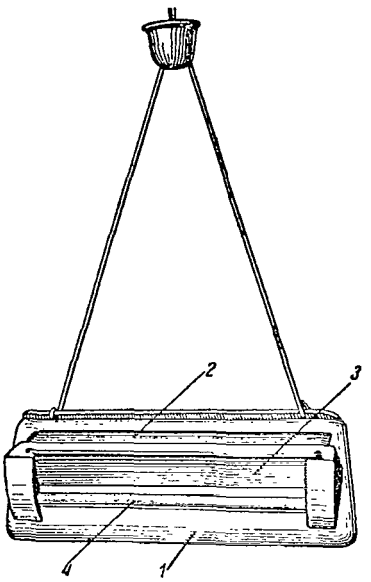


Fig. 27. Wall-Mounted Bactericidal Lamp.

It is recommended that the lamps be shut off for one and one half hours after every two to three hours of use in order to reduce concentration of ozone in the air. This substance is formed while the bactericidal lamps are burning.

§ 8. SUNLAMPS /35

Sunlamps are those incandescent lamps which produce longwave ultraviolet radiation. The sunlamp is a mercury lamp operating at low pressure, whose tube is made of a special type of uviol glass which is transparent to longwave ultraviolet radiation. The walls of the tube are covered on the inside with a phosphor that gives off ultraviolet radiation from 285 to 380 mμ, corresponding to zones A and B. The majority of the radiation is given off in the 310-320 mμ range, i.e., the same ultraviolet portion of the spectrum occupied by the light from the summer sun which reaches the Earth's surface. Hence, sunlamps are used widely for prophylactic radiation.

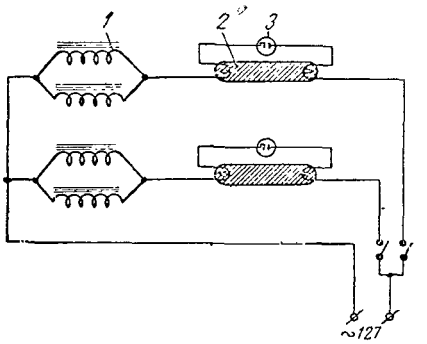


Fig. 28. Schematic Diagram of Circuit for Wall-Mounted Bactericidal Lamp.

At the present time, sunlamps of type EUV-15 are being produced, with a nominal power of 15 W. The radiation spectrum of the lamp in percent of radiation with a wavelength of 310 mμ is shown in Figure 29. The shaded area corresponds to the continuous spectrum of radiation from the phosphor, while the lines represented by dashes show the mercury vapor lines which pass through the phosphor.

The electrical components for the sunlamp are completely analogous to the bactericidal lamps just discussed.

The sunlamp can be used separately in the holders which were described in the preceding section for bactericidal lamps. More

often, however, the sunlamp is mounted in a lighting fixture along with a group of incandescent lamps to illuminate an area where there is a lack of natural sunlight (e.g., in underground locations or in the Far North in nurseries, schools, hospitals, etc.).

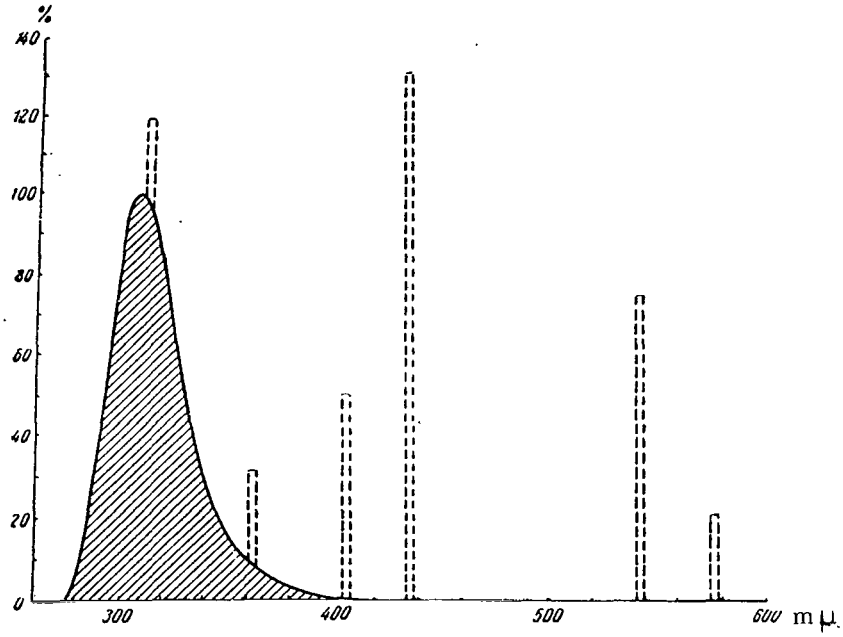


Fig. 29. Irradiation Spectrum of Sunlamps.

CHAPTER II

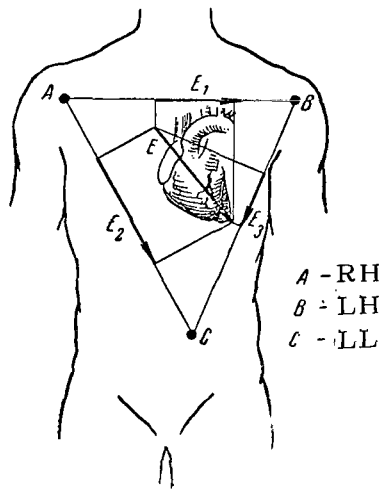
ELECTROCARDIOGRAPHS

PART 1

PHYSICAL PRINCIPLES AND METHODS OF RECORDING BIOPOTENTIALS

The potentials which arise during the function of various organs are called biopotentials; e.g., they can be obtained from the heart or brain, as well as from the muscles of the support and motor apparatus. The potential differences formed between certain points or sections of an organ produce currents in the surrounding tissues, called biocurrents. If metal electrodes are placed on the corresponding locations on the surface of the organ, the biopotentials can be detected, measured, and recorded accurately. Biopotentials can also be measured or recorded by placing electrodes on certain locations on the surface of the body. /36

The method of recording by biopotentials of the heart is called electrocardiography. The recording of the basic biopotentials of the heart is accomplished with three electrodes, placed at locations corresponding to the vertices of a triangle ABC (Fig. 30), in the center of which the heart is located.



The potential differences between each pair of these electrodes is recorded separately: A-B, A-C, and B-C; these are referred to as leads I, II, and III. Each of these potential differences is viewed as a projection of vector E of the EMF of the heart, directed approximately along the anatomical axis of the heart on a line joining the points where the electrodes are applied or the corresponding side of the triangle ABC.

Fig. 30. Relationship of Potentials Recorded in Electrocardiography, and the EMF of the Heart.

Comparing the curves showing the variations of these potential differences enables us to get an approximate idea regarding the changes in the vector of EMF of the heart during one cycle of its action.

In actual practice, the electrodes are not applied to the three points mentioned above, but rather to more suitable locations which are of equal value from the electrical standpoint on the inside of the left forearm (left hand electrode, or LH), the right forearm (right hand electrode, RH), and on the left shin (left leg electrode, LL). Recently, a chest electrode (CE) has been added to this group, so that the requality of the recordings has been considerably improved. It is also possible to use another electrode attached to the right shin (right leg electrode, RL); it has an auxiliary function, being connected to the chassis of the apparatus and grounded. /37

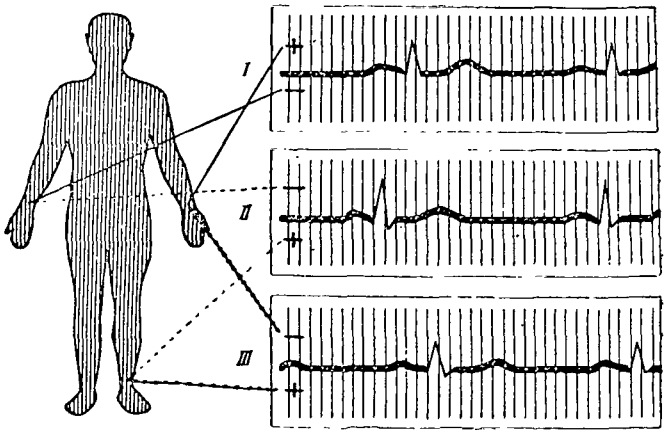


Fig. 31. Electrocardiogram of a Healthy Individual (Leads I, II, III).

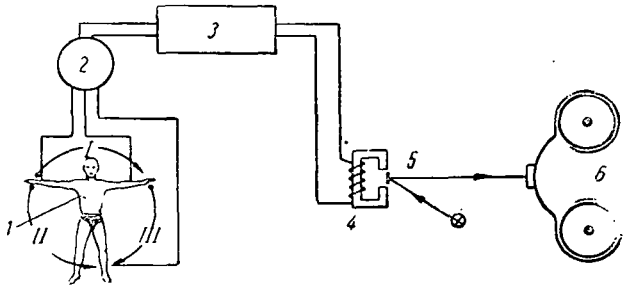


Fig. 32. Diagram of System for Recording Cardiac Biopotentials.

Biopotentials are periodic oscillations of changing sign and complex nonsymmetric appearance. A typical example of the nature of the appearance of an electrocardiogram as recorded with the different leads in a healthy individual is shown in Figure 31. The periodicity of the repetition of the oscillations corresponds to the pulse rate, while the amplitudes of the peaks are on the order of several millivolts.

The apparatus for recording cardiac biopotentials, or the electrocardiograph, consists of three basic parts: (a) the input mechanism or "lead switch", to which the electrodes are attached, (b) the amplifier, and (c) the recording mechanism.

A diagram of the system for recording electrocardiograms using photographic film is shown in Figure 32. The numbers

in the figure represent the following: (1) patient with electrodes applied to his body (three principal leads are shown: lead I, right hand - left hand, II, right hand -left leg, and III, left hand - left leg); (2) lead switch; (3) amplifier; (4) galvanometer; /38 (5) optical recording system; (6) film-transport mechanism.

An electrocardiograph which has only one amplifier is referred to as a single-channel instrument and permits recording of only one process at a time. Recording from the three leads is done in turn. Portable electrocardiographs are usually of the single-channel variety, although they may have two channels on occasion. There are also large stationary electrocardiographs with five or six channels, in which simultaneous recording of electrocardiograms from several leads can be performed simultaneously, in addition to the recording of several other processes related to cardiac activity: heart sounds and noises, pulse waves, etc.

A more complex method of studying cardiac biopotentials, called vector electrocardiography is also used. In the simplest form of electrocardiography, the same three standard leads are used to record the curves of vector change, each of which is the geometric sum of any two of the three projections of the vector of the EMF of the heart in the directions AB, AC, or BC. The curve which represents the variation of such a vector during an operating cycle of the heart, is called the vector electrocardiogram. Recording is performed by means of a electron-beam oscillograph, in which the potential differences formed between the electrodes at any two of the fixed leads, are combined geometrically. The vector electrocardiogram then appears on the screen of the oscillograph.

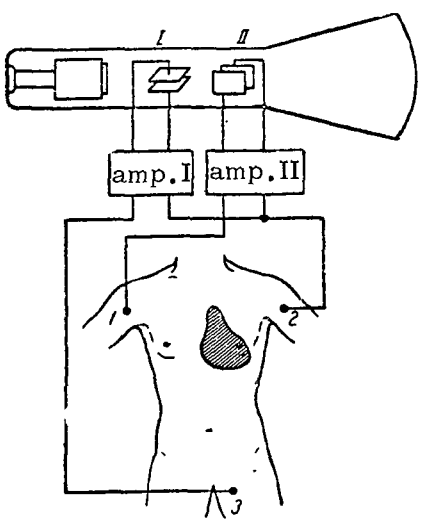


Fig. 33. Diagram of Observation of a Vector Electrocardiogram.

We know from electronics that if two alternating voltages are applied to two pairs of deflecting plates in the electrostatic control of a cathode ray tube (or if these voltages are applied to two control coils or electromagnetic control devices), a curve appears on the screen which is the result of the geometric combination of the vectors of their instantaneous values, called a Lissajou figure. From the physical standpoint, the vector electrocardiogram is a Lissajou figure, obtained by combining the instantaneous values of the cardiac potential differences on the screen of the cathode ray tube; these potential differences are obtained from two separate pairs of electrodes. For example, Figure 33 shows a method of recording vector electrocardiograms by means of electrodes using leads I and III. Figure 34 shows a schematic

representation of a vector electrocardiogram, obtained by combining two oscillations of different type in cardiac potential differences, represented in the form of electrocardiograms which are usual for lead I in a healthy individual. The vector electrocardiogram is a combination of three loops, corresponding to the three peaks of an electrocardiogram: P, QRS and T.

Still more complex methods of obtaining vector cardiograms have been devised which employ additional electrodes, such as a fourth electrode fastened to the back. This means that the lines joining the points where the electrodes are applied form a three-dimensional figure, called a tetrahedron, within which the vector of cardiac EMF is located. /39

The vector electrocardiogram makes it possible to get a much more detailed picture of the changes in values and direction of the vector of cardiac EMF during a cardiac cycle; this means that the results are more detailed than those obtained when using a simple electrocardiogram, since the bioelectric phenomena accompanying cardiac activity can be studied.

Vector electrocardiography requires the use of special devices called vector electrocardioscopes. They are based on a cathode-ray oscillograph, used to observe low frequency processes. The first vector electrocardioscope in the Soviet Union was designed by I. T. Akulinichev.

The amplifiers for recording biopotentials have high sensitivity. This means that they are very subject to all inductive influences, or (as they are called) inductances. Electrical and magnetic fields from instruments, devices or electrical wiring (particularly power lines), electromagnetic waves passing "through the ether", located in the vicinity, can produce additional potentials on the electrodes which have been applied to the patient. Although they are small in value, these potentials are amplified by the apparatus and can be recorded along with the process being measured, so that they disturb the recording. This means that the electrocardiograph must be located so that there are no sources of strong electromagnetic fields in its vicinity. As a rule, the electrocardiograph must be placed in a special

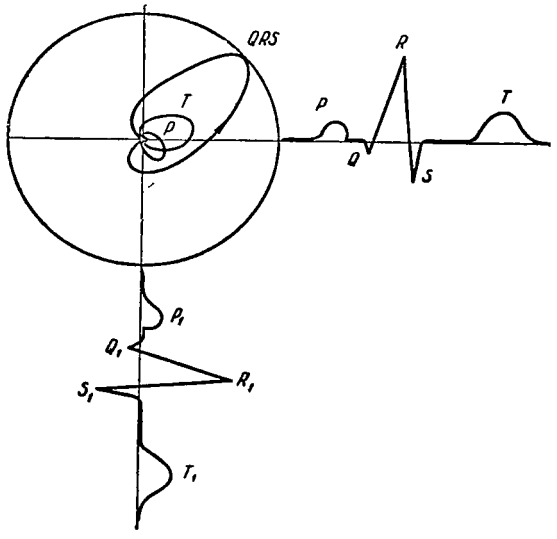


Fig. 34. Schematic Representation of a Vector Electrocardiogram.

shielded room at the end of the building which is opposite the X-ray and physiotherapeutic departments. There must not be any main power lines near the electrocardiography department, nor should the apparatus be installed in a location which is near a streetcar or trackless trolley line.

The electrodes must be applied with great care, since the contact between the electrode and the skin determines the quality of the pickup of the currents and the stability of the zero line in the recording. Usually a piece of flannel or filter paper is placed between the electrode and the skin, moistened with a warm 5-10% solution of sodium chloride and squeezed slightly to remove excess moisture. The area covered by this material must not be much greater than the area of the electrode. To reduce the pickup of extraneous signals, it is recommended that the skin over an area somewhat larger than the area of the electrodes be wiped with alcohol, and that special paste be used instead of the piece of material. The paste is spread in a thin layer over the skin.

The electrodes on the extremities are held in place by elastic straps. The straps do not have to be tightened. The chest electrode is usually held in place by a rubber suction cup. Improper application of the chest electrode is often a source of stray currents. /40 After use, the electrodes and the elastic straps must be washed with water and dried.

While the recordings are being made, the patient must be lying down, with his muscles relaxed.

The electrodes are attached to the input of the apparatus by plugs and wires. It is necessary to check the quality of these contacts, to clean soiled surfaces, and to keep the pins of the plug-in connectors separate.

PART 2

LOW-FREQUENCY AMPLIFIER

It will be recalled that the operation of an amplifier is based on the dependence of the current in a triode on the grid potential: a positive potential on the grid increases the anode current of the tube while a negative potential reduces it. A schematic diagram of a very simple amplifier with a triode is shown in Figure 35, a; a graph explaining its operation is shown in Figure 35, b. A resistance R_a is connected in series with the power supply in the anode circuit of the tube. A voltage u_c, which is to be amplified, is applied to the grid of the tube. The voltage oscillations on the grid produce oscillations of the anode current I_a (Fig. 39, b). Current I_a produces a voltage drop across resistance R_a, which has a pulse-type appearance. The alternating component U_a of this voltage is fed through a blocking capacitor C_p and becomes the amplified voltage: $U_a = ku_c$, where k is called the amplification factor.

In amplifiers intended for use in devices for recording biopotentials, it is necessary that the shape of the voltage at the output corresponds exactly to the shape of the voltage applied to the grid, i.e., the amplifier must operate without distortion. Distortion can be divided into two types, nonlinear and frequency.

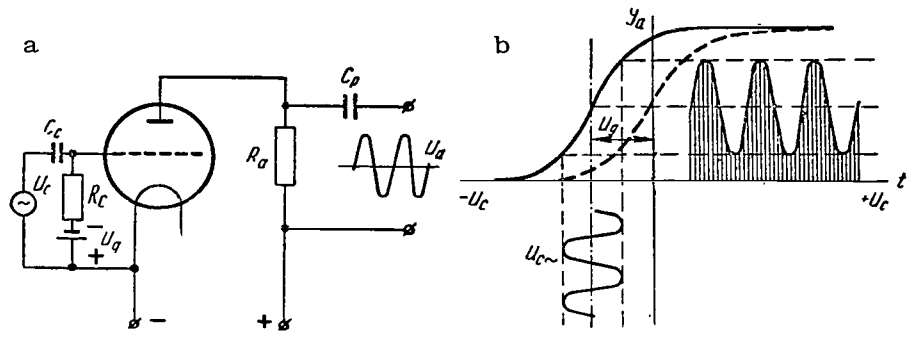


Fig. 35. Schematic Diagram (a) and Graph of Operation (b) of a Very Simple Amplifier.

Nonlinear distortion is observed when the tube is operating beyond the straight line portion of the anode-grid characteristic, and it is also related to the appearance of a grid current on the grid in the positive half-cycles of the voltage, accompanied by a drop in the voltage across the internal resistance of the grid potential source and consequently by a drop in the actual potential on the grid. To prevent nonlinear distortion, the operating regime of the amplifier is limited to the straight line portion of the grid characteristic. In addition, by increasing the anode /41 voltage and applying an additional constant negative voltage to the grid (Fig. 36, a), the grid characteristic along with the operating current are biased so that the potential on the grid remains negative and the amplifier works without a grid current (Fig. 36, b).

The bias voltage is applied to the grid either from a separate source (Fig. 36, a) or the voltage drop from the constant component of the anode current across the resistor connected in the cathode circuit (Fig. 37) is used. Resistance Rk is shunted by a capacitor Ck of rather high value, through which the alternating component of the anode current passes.

In amplifiers using directly heated tubes, powered by direct current, the bias voltage can be obtained by using a resistance connected in series in the heating circuit, in the wire which is connected to the negative terminal of the amplifier (see, e.g., Fig. 44).

Note that in the circuit shown in Figure 37, the amplified

voltage is not obtained across resistance R_a, connected in the anode circuit of the tube, but from the resistance R_x, which is connected parallel to the tube through the blocking capacitor C_p. The principle by which the amplified voltage is formed remains the same.

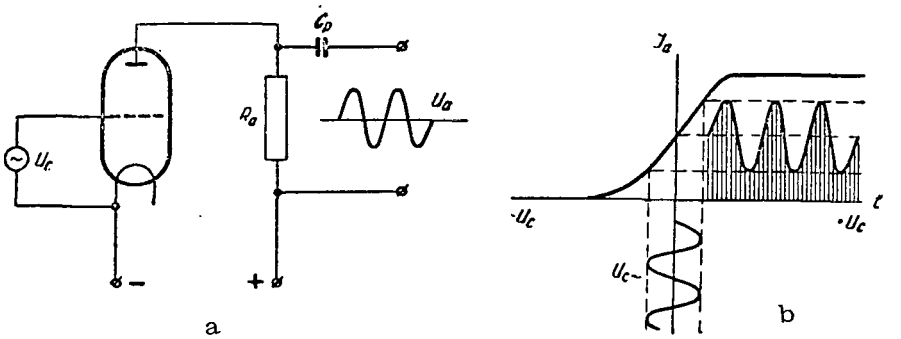


Fig. 36. Schematic Diagram (a) and Graph of Operation (b) of an Amplifier With Grid Bias.

A resistance R_c is usually connected between the grid and the cathode of the tube (Figs. 36 and 37); this resistance is necessary to ensure leakage of the electrons which reach the grid, especially when there is a blocking capacitor C_c in the grid circuit. The leak resistance, along with the capacitance of the blocking capacitor, produces a time constant of the grid circuit, which is important for the operating characteristics of the amplifier.

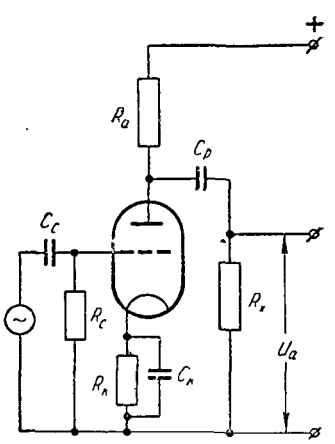


Fig. 37. Schematic Diagram of an Amplifier With Bias at the Expense of the Anode Current.

Frequency distortion is caused by the fact that the value of the capacitances and inductances (e.g., the windings of the electromagnets in the galvanometer) in the amplifier circuit depend on frequency. Therefore, the amplification factor for simple (harmonic) oscillations, into which a given oscillation of complex form can be divided, will be different. This produces a distortion in the shape of the voltage at the amplifier output relative to the voltage on the grid. This distortion is taken into account by means of a frequency characteristic of the amplifier, which shows the dependence of the amplification factor k on the frequency ν of the harmonic oscillations (Fig. 38). The characteristic has a central portion which is nearly horizontal and drops off in regions of both high and low frequencies. The limits of the oscillation frequency, corresponding to the horizontal

/42

portion of the characteristic and therefore to undistorted amplification, are called the pass band of the amplifier. The pass band of the amplifier must correspond to the limits of the harmonic spectrum (i.e., the range of frequencies of harmonic oscillations, into which a complex oscillation can be subdivided), relative to the amplification of the oscillations.

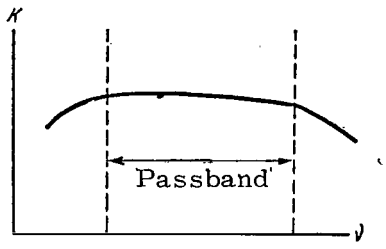


Fig. 38. Frequency Characteristic of an Amplifier.

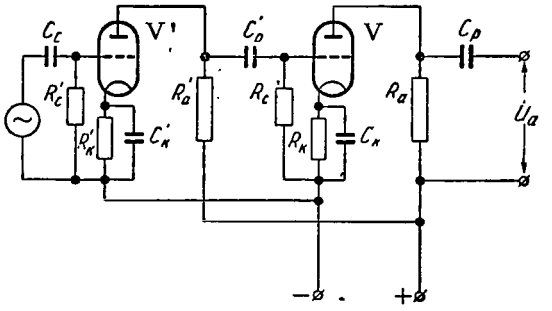


Fig. 39. Schematic Diagram of a Two-Stage Amplifier with Resistance-Capacitance Coupling.

For example, electrocardiograms generally involve low frequencies within the limits of 1-10 Hz, while the complete harmonic spectrum of an electrocardiogram contains frequencies from 0.5 to 100 Hz. Therefore, the frequency characteristic of the electrocardiograph must have a horizontal portion which begins at the very lowest frequencies on the order of a single Hz. At the same time, it is desirable to have a steep drop in the characteristic in the high frequency region (above 100 Hz), so that the amplifier will not pass currents of higher frequency, such as the biocurrents of the muscles, which are picked up by the electrodes, extraneous currents, etc.

When the amplification of a single tube is insufficient, the voltage amplified in the first tube is passed through a blocking capacitor to the grid of a second tube, etc. This produces a multistage or multicascade amplifier. The simplest form of a two-cascade amplifier with grid bias from the anode current is shown in Figure 39.

To record biopotentials, amplifiers with resistance-capacitance coupling between the cascades to ensure minimum distortion are used. An amplifier of this type cannot amplify direct current because of the blocking capacitors in it. The capacitors are charged when direct current is applied to the input of the amplifier and amplified voltage appears at the output of the amplifer, but the capacitors then gradually discharge through their shunt resistors, and the voltage at the output of the amplifier decreases. The rate of this decrease depends on the values of the resistors and capac-

itors in the grid circuits of the amplifier and is characterized by a "time constant", i.e., the time in which the voltage at the output (at a constant voltage at the amplifier input) decreases to $\frac{1}{e} = \frac{1}{2.72} = 0.37$ of the initial value. The time constant of the amplifier characterizes the degree of distortion of the low frequency oscillations (below 1 Hz), which bear a greater resemblance to the constant current. The greater the time constant, the smaller the distortion of the oscillations. The time constant in electrocardiographs is on the order of 1.5-1.8 sec. /43

A push-pull circuit can also be used in amplifiers (Fig. 40, a). The alternating voltage u_c which is to be amplified is applied between the grids of two tubes. This means that the grid potentials as well as the oscillations of the anode current in the tubes will be out of phase with the average current between the cathodes; when the anode current in one tube is increasing, it is decreasing in the other, and vice versa. Since the power supply is connected to the middle of resistance R_a, the alternating components of the voltage drop, formed by the anode currents of the tubes in both halves of this resistance, will be in opposite directions, but since they are also of opposite phase, i.e., opposite in signs, they will cancel each other out in resistance R_a. Therefore, the total voltage which can be obtained from this resistance through the blocking capacitors (as we can see in the diagram) agrees completely in its shape with the voltage applied between the tube grids but has a much greater amplitude.

Usually, a bias voltage u_g is applied to the tube grids, so that the anode-grid characteristics of the tubes are shifted, as shown in the graph representing the operation of the amplifier (Fig. 40, b). The graph shows the grid characteristics of the tubes, plotted in opposite directions corresponding to the connection of the tubes in the circuit. The balance of the curve is analogous to that of a graph of the simple (one-stage) circuit (Fig. 35, b).

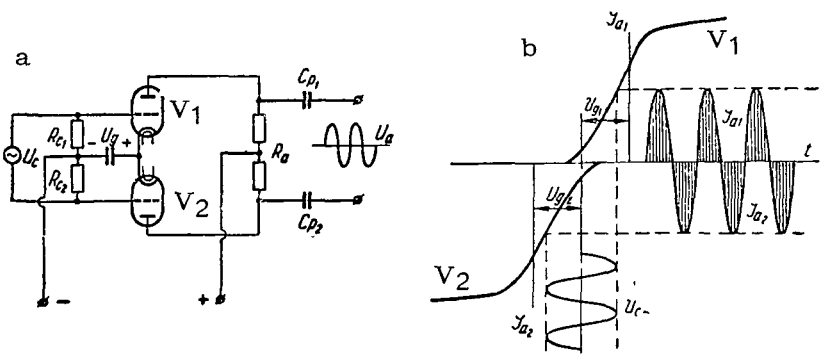


Fig. 40. Push-Pull Circuit (a) and Graph of Operation (b) of a Simple Amplifier.

If an alternating voltage is applied to the amplifier, forming a potential on the grids of both tubes which is uniform with respect to the common point between the cathode, cophasal (i.e., in-phase) oscillations of the anode current in both tubes will occur. In this case, the alternating components of the anode currents of the tubes, acting in opposite directions, cancel each other out. Practically speaking, the incomplete symmetry of both halves of the circuit prevents complete cancellation from occurring, although the cophasal signals in a push-pull amplifier are amplified to a much smaller degree than the working signals which are applied to the grids of the tubes during antiphase.

In this connection, the push-pull amplifier is called a differential amplifier; it is widely used in instruments for recording biopotentials, since it considerably decreases the influence of stray potentials which are largely cophasal with respect to the grids of the two tubes. This property of the differential amplifier can be increased still further by using a strong negative feedback. /44

Negative feedback is produced by applying a portion of the voltage obtained at the output of the amplifier, to its input; i.e., the voltage is fed from the anode circuit to the grid circuit. The feedback can be positive if the voltage on the grid is in-phase with the input signal, so that the amplification factor increases. A positive feedback is used primarily in generators. Feedback can be negative when the voltage on the grid is out of phase with the input signal, so that the amplification factor is reduced. Negative feedback is frequently employed in low-frequency amplifiers, where it reduces distortion and increases the stability of the amplifier operation.

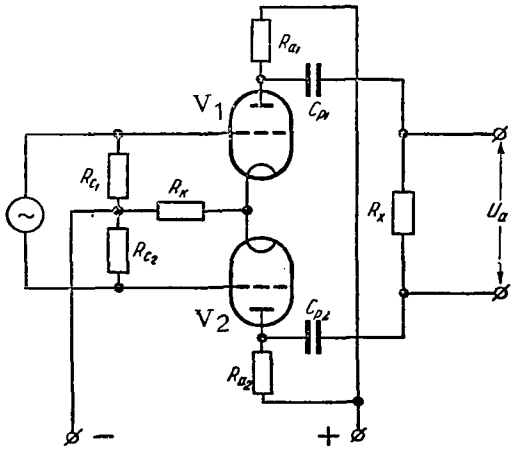


Fig. 41. Push-Pull Circuit for an Amplifier With Negative Feedback.

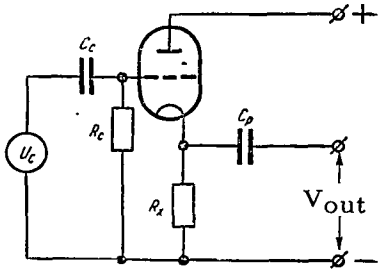


Fig. 42. Schematic Diagram of a Cathode Repeater.

Negative feedback is usually accomplished by connecting a resistance lamp R_k (Fig. 41) in the common cathode circuit; in this case, the lamp is not shunted by a capacitor and all of the anode current passes through it.

Negative feedback in a differential amplifier makes it possible to reduce the amplification of cophasal signals (i.e., interference) to a considerable degree. At the same time, however, negative feedback using a resistor R_k is practically never used for antiphasal oscillations (i.e., for the working signal); these oscillations, passing through resistance R_k and being out of phase, are reduced, and in the case of complete symmetry of the circuit, they cancel one another out.

In some instruments (not only electrocardiographs), a special form of tube cascade is found, called the cathode repeater (Fig. 42). The latter consists of a triode, to whose grid controlling signals are applied; the cathode circuit contains a resistance R_x, which acts as a load or a resistance to reduce the output voltage. The voltage across the resistance R_x, as in the usual amplifier circuit, reproduces the shape of the signals which are fed through the tube grid but the amplification factor in this case is less than unity due to the strong negative feedback produced by this resistance. The purpose of a cathode repeater, which is usually included after the amplifier stage, is to match the output resistance of the amplifier with the low-ohmage load resistance.

Conventional amplifier circuits usually contain tubes (pentodes) which contain two other grids besides the control grid: a screen grid and a protective grid, which considerably improve the operating characteristics of the tube. /45

It will be recalled that the screen grid (the next one after the control grid), to which a constant positive voltage is applied which is close in value to the anode voltage, reduces the effect of voltage changes in the tube anode upon the anode current. These variations occur in connection with the voltage variations across the anode resistance R_a. In addition, the screen grid reduces the capacitance between the anode and the control grid, which has a detrimental effect on the operation of high-frequency amplifiers and generators. The screen grid is usually connected to the positive pole of the power supply through an additional resistance R_s and connected to the cathode through a capacitor C_s (see Fig. 43).

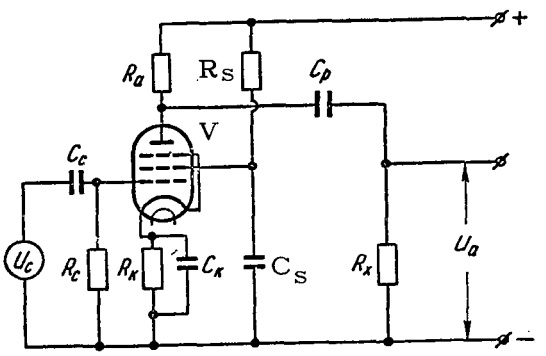


Fig. 43. Schematic Diagram of a Pentode Amplifier.

The protective grid (located between the screen grid and the anode) is intended to prevent the formation of a current of secondary emission between the anode and the screen grid when the potential of the latter is greater than the anode potential. The screen grid is connected to the cathode and sends secondary electrons back to the anode thanks to its negative potential.

There is a special type of tube called the beam tetrode, whose characteristics are similar to those of a pentode.

Because of the special design of the electrodes and the presence of control screens around the anode, which are connected within the tube with the cathode, conditions are produced in these tubes which resist the formation of a secondary-emission current from the anode to the screen grid.

A schematic diagram of a pentode amplifier is shown in Figure 43.

PART 3

BATTERY-POWERED PORTABLE ELECTROCARDIOGRAPHS

§ 1. ELECTROCARDIOGRAPHS EKP-4 AND EKP-5

The Union Factory EMA produces a portable, single-channel electrocardiograph (type EKP) powered by dry batteries or storage batteries, and using photoelectric recording on film. The type EKP-4M and EKP-5M may be encountered in practice. At the present time, the factory is producing the EKP-60.

These devices are basically similar in design, but each differs from the others with respect to some improvement in one or another component. The EKP-4M permitted recording of electrocardiograms only with three standard leads, it used the amplifier based on the old type CO tubes, and was fitted with a rather simple form of vibration galvanometer.

In the EKP-5M electrocardiographs, the number of recording leads was increased to 10, permitting two film-transport speeds (50 and 100 mm/sec); the amplifier uses modern bantum tubes. An improved galvanometer was installed, and there were a number of other improvements in design. /46

These instruments are powered by dry batteries BAS-G-80 (EKP-4M) or BAS-G-60 (EKP-5M) and an alkaline battery 2 NKN-10. The instruments were also fitted with copper oxide rectifiers for charging the batteries from line voltage.

The EKP-60 electrocardiograph is the result of further improvements to the EKP-5M, especially with regard to its power supply, which uses batteries alone. The amplifier and recording section

of the EKP-60 are similar to those of the EKP-5M with certain small exceptions. A detailed description of the EKP-4M and EKP-5M will be found in the Second Edition of this book (1960).

§ 2. EKP-60 ELECTROCARDIOGRAPH

The apparatus is a portable, single-channel electrocardiograph with photoelectric recording. The recording of the electrocardiograms can be made from any of ten leads: three standard, three amplified, and four chest leads, necessitating the attachment of five electrodes to the patient: four on the extremities and a fifth on the chest.

The recording is made on a strip of cardiographic paper, 35 mm wide, or on a strip of film with a sensitivity of 45-180 units according to the State National Standard. The transport speed of the film is 50 mm/sec. The capacity of the cartridge is as follows: 15 m on the feed reel, 6 m on the take-up reel. Time markings are made at 0.05 sec intervals.

The maximum sensitivity of the apparatus is 15 mm/mV. The amplitude of the recording is proportional to the input voltage, with an accuracy of up to ± 5% within the limits of the recording amplitude from 3 to 20 mm and an input voltage of up to 3 mV (effective).

The frequency characteristics of the amplifier are as follows:

Frequency, Hz	25	50	75	100
Relative amplification	1.0	0.8	0.5	0.4

Time constant at least 1.5 sec.

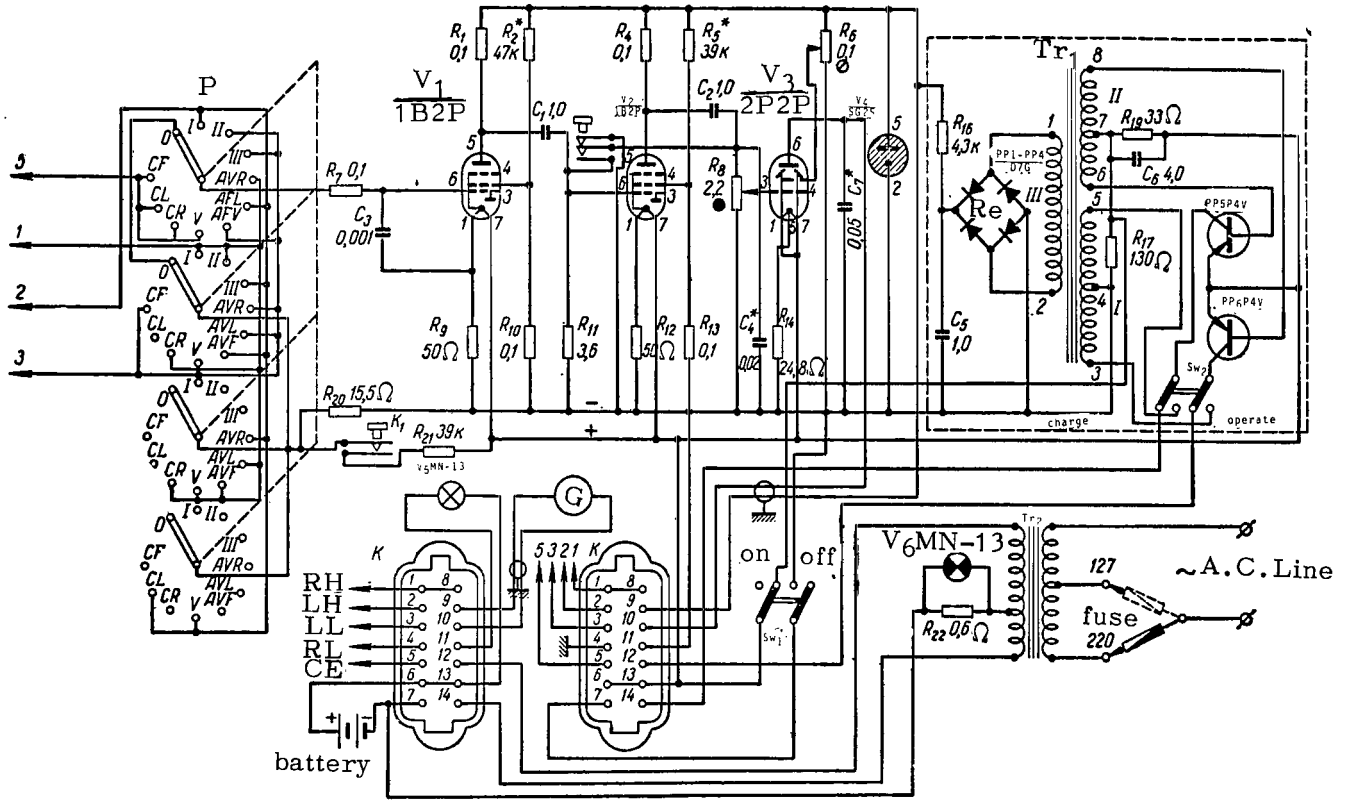
Apparatus powered completely by 2NKN-10 battery.

External dimensions: 275 × 175 × 402 mm. Weight 11 kg.

The apparatus consists of three basic parts: amplifier, recorder, and power supply.

The schematic diagram of the electrocardiograph is shown in Figure 44. The amplifier has three cascades with resistance-capacitance coupling. The first two stages use 1B2P pentodes, while the third (output) stage uses a 2P2P beam tetrode.

The wires from the RH, LH, LL, RL, and CE electrodes, combined in one "lead plug", are plugged into a recepticle K (1-5 contacts). Here the lead 4 from the right leg is grounded to the chassis, while leads 1, 2, 3 and 5 are connected to the lead switch S. From the switch, two wires run to the grid and cathode of the input tube V_1 of the amplifier. The grid circuit also contains a leakage resistance 7, while the cathode circuit contains a resistance 20 which forms a voltage divider with resistance 21 for the calibrating signal of 1 mV, which is fed through the tube grid (in the form of a positive bias) by means of button B_1. The input of the tube is shunted by capacitor 3 to remove high-frequency noise. The heater circuit of tube V_1 contains resistance 9, which forms a constant negative



NOTES: * Adjusted in Calibration; • Regulated from Control Panel;
◐ Regulated Below Slit

Fig. 44. Schematic Diagram of EKP-60 Electrocardiograph

bias voltage on the grid (resistances 12 and 14 in tubes V_2 and V_3). The voltage amplified in the first tube passes through blocking capacitor 1 to the grid of the second tube V_2 (a leakage resist-/48 ance 11 is connected to the grid of tube V_2). The screen grid of tube V_1 receives voltage from the divider through resistances 2 and 10.

The voltage amplifief by the second tube passes through the blocking capacitor 2 to potentiometer 8; the grid of the output tube V_3 is connected to the slider of this potentiometer. Potentiometer 8 is used to regulate the sensitivity (amplification) for each recording. The anode circuit of tube V_3 is connected to the adapter K by a shielded wire (contact 10) and then to galvanometer G. A second wire runs to the galvanometer (also shielded) through contact 9 on adapter K from the power supply.

Capacitors 7 and 4 are connected in the anode and grid circuits of tube V_3, and are used to improve the frequency characteristic of the amplifier; their values are selected when the instrument is calibrated. The voltage on the screen grid of output tube V_3 comes from potentiometer 6, the knob of which is located "below the slit", and can be used when necessary for adjusting the sensitivity (amplification).

The grid circuits of the second and third tubes can be connected directly with the cathodes by pressing button K_2, called the "damper". This produces a considerable decrease in the time constant of the intermediate circuits thus facilitating a rapid establishment of a normal regime in the amplifier after the apparatus is switched on or after the recording leads are changed. The damper is used to hasten the return of the light beam to the recording isoline (zero line).

The power for the anode circuits of the amplifier comes from a transistorized converter, powered by the same battery as the heater circuit of the amplifier. The converter consists of the converter itself, operating on two P4V transistors (represented by PP_5 and PP_6 in the diagram), transformer Tr_1 and rectifier Re. The converter, operating as a blocking generator, converts the direct current from the battery at a voltage of 2.5 V into alternating current.

The voltage from the step-up winding of the transformer is rectified by rectifier Re consisting of four semiconductor diodes (D7G, represented by PP_1-PP_4 in the diagram), with a ripple filter (R_{16} - C_5) and a stabilitron SG-2S (V_5) connected to the output. The voltage supplied to the anode circuit is 70 V.

Transistors are used as rectifiers when charging the battery from line voltage. The voltage from the step-down winding of the transformer Tr_2 passes through contacts 12 and 14 of the adapter and then through the contacts of toggle switch Sw_2 to the collectors of the transistors. The bases of the transistors are connected

to the positive pole of the battery through the center-tap of winding P of transformer Tr_1 (to the end leads of which they are connected), the circuit of the contacts of toggle switch Sw_1 and contacts 6-13 of adapter K. The negative pole of the battery is connected to the center-tap of the secondary winding of transformer Tr_2. Resistance 22 is connected in this circuit, and the voltage drop across it powers the pilot lamp V_6.

Toggle switch Sw_2 is used to switch the transistors when the battery is charged, so that they operate as converters.

The collectors of the transistors are connected to the ends of winding 1 of transformer Tr_1, whose center-tap is connected to the negative pole of the battery by the contacts of toggle switch Sw_1 and contacts 7 of adapter K. The positive pole of the battery is then connected to a common point with the emitters by the contacts 6-13 of adapter K (and also by a common positive connection with the tube-heater circuit), and connected in parallel with the center- /49
tap of winding II of transformer Tr_1.

Toggle switch Sw_1 switches on the power for heating the tubes in the amplifier, while in the "off" position it turns on the battery-charging circuit. When the heaters are switched on, the voltage from contact 11 on adapter K is fed to pilot lamp V_5.

Resistance Data

1	MLT-0.5-100 kΩ ± 10%-A
2	MLT-0.5-47 kΩ ± 10%-A
4	MLT-0.5-100 kΩ ± 10%-A
5	MLT-0.5-39 kΩ ± 5%
6	SPO-0.5-100 kΩ -4 MM
7	MLT-0.5-100 kΩ ± 10%-A
8	SP-1 OS-3 20A 2 W-2.2 MΩ
9	ULI-0.25-50 Ω ± 2%
10	MLT-0.5-100 kΩ ± 10%-A
11	MLT-0.5-3.6 MΩ ± 10%-A
12	ULI-0.25-50 Ω ± 2%
13	MLT-0.5-100 kΩ ± 10%-A
14	ULI-0.25-24.8 Ω ± 2%
16	MLT-0.5-4.3 kΩ ± 5%
17	VS-0.25-130 Ω ± 10%
19	VS-0.25-33 Ω ± 10%
20	ULI-0.25-15.5 Ω ± 1%
21	MLT-0.5-39 kΩ ± 10%-A
22	Wire-wound 0.6 Ω

Capacitor Data

1	MBGP-3-200-A-1-P
2	MBGP-3-200-1-P
3	MBG-I-200-0.001-P
4	KBG-I-200-0.02-P
5	MBM-160-1.0-P
8	MBGO-2-160-4.0-P
7	MBM-160-0.05-P

Note that in the EKP-60 instruments which were produced until 1963, the schematic diagram of the power supply is slightly different in that a separate semiconductor rectifier is used for charging the battery.

Figure 45 is a sketch of the optical system of the apparatus. The illuminator consists of an incandescent lamp 1, the light from which (with the aid of lens 2) passes partly through lens 3 onto mirror 4 of the galvanometer and partly onto mirror 6 of the time

marker. The light reflected from the mirrors is focused onto the film 7 by means of a cylindrical planoconvex lens 5. A portion of the rays reflected from the mirror on the galvonometer strikes the inclined mirror 10 and after being reflected upward, is focused by lens 8 on a monitoring screen 9 for observation.

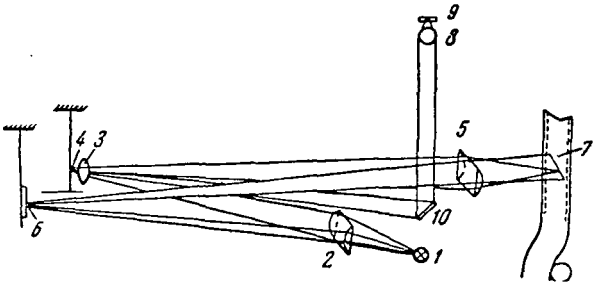


Fig. 45. Diagram of Optical Recording in the EKP-60 Electrocardiograph.

The vibrating galvanometer used in the instrument (Fig. 46, a; the figure shows the galvanometer with the cover removed) consists of a solid framework 1 whose lower section contains a permanent magnet with two tapered pole pieces 2. Between them is a coil 3, inside of which is an armature 4 in the shape of a strip of soft iron. One end of this strip is fastened to the framework while the other end is free to move between the pole pieces 2. This end of the strip is fastened to one end of a wire, to which is fastened mirror 6. The wire is a thin, elastic, previously twisted strip of phosphor bronze, stretched between the end of the armature 4 and the support 8, mounted in a special holder at the bottom of the galvanometer framework (Fig. 46, b). /50

The operating principle of the galvanometer (Fig. 46, b) is as follows. The basic constant magnetic flux Φ_0, passing through the poles of the core 2 (Fig. 46, a), is increased by a variable magnetic flux $\Delta\Phi$, formed by the current which passes through coil 3 of the electromagnet. Flux $\Delta\Phi$ passes through the armature 4 and through the pole of the core in two parallel branches. In one branch (e.g., the upper one in Fig. 46, b) these fluxes are of the same sign, so that a stronger flux acts on the armature ($\Phi_0 + \Delta\Phi$); the currents are opposite in sign in the other branch, so that a less powerful flux acts on the armature ($\Phi_0 - \Delta\Phi$). As a result, the armature moves toward the upper pole. When the flux produced by coil 3 changes direction, the relationship of the fields changes in the poles of the core and armature 4 moves toward the lower pole, etc. The movements of the armature correspond to the variations in the current passing through coil 3, i.e., in this case they correspond to the changes in the current from the output tube of the amplifier, which in turn reproduced the form of the oscillations supplied to the input of the amplifier by the biopotentials.

When armature 4 vibrates, wire 5 (Fig. 46, a) stretches or relaxes. Since the wire was initially twisted, this causes it to curl or uncurl slightly and the mirror attached to it oscillates in the plane perpendicular to the axis of the galvanometer. These oscillations reproduced the fluctuations in the current passing

through the coil of the electromagnet. The wire passes through a damper 7, consisting of a wire ring in which a drop of viscous liquid is located.

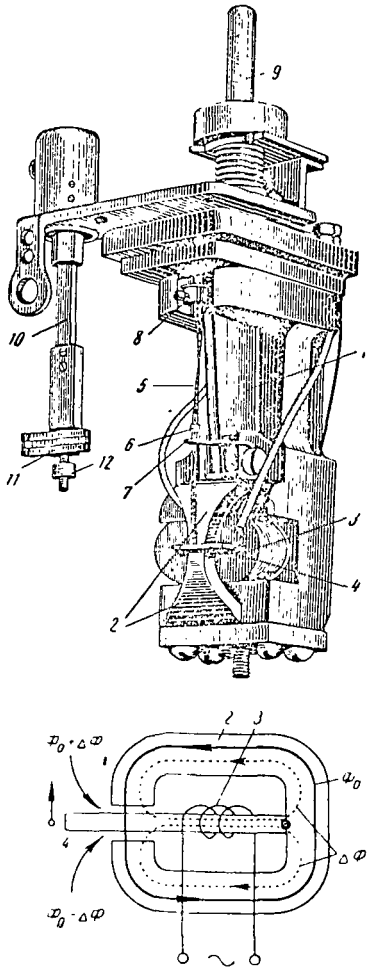


Fig. 46. Vibrator of the EKP-60 Electrocardiograph. (a) Overall View; (b) Diagram of the Electromagnet.

The tension of the wire carrying the mirror, and consequently the setting of the light beam to a central position, is adjusted by turning screw 9. The lower end of screw 9 passes through an opening in the end of the frame 1 and rests on a lever to the end of which is connected the wire holder 8. The wire holder is moved up and down by turning the screw.

The galvanometer is attached to the control panel by three screws, which can be adjusted to change the angle of the axis of the galvanometer and thereby to center the light beam on the film. Screw 9 passes through an opening in the panel and is fitted with a knob, called the corrector. This knob can be used to regulate the position of the light beam across /51 the width of the film.

On the side of the galvanometer, there is a time marker which consists of a pendulum (a flexible strip with a weight 12) and a wide mirror 11 attached to it. The time marker is set to vibrating by a special plunger, connected to the starting handle of the film-transport mechanism by a flexible rod. Pendulum 10 is mounted so that the ray of light reflected from the mirror on the time marker falls on the center of the paper strip. The path of the beam from the time marker to the film is regulated by turning the pendulum on its own axis, and also by turning the mirror mount.

The apparatus (Fig. 47) is mounted in a metal case in the shape of a suitcase, with a hinged lid and a handle for carrying. The front of the case is fitted with a removable cover OK at the bottom, which provides access to the compartment in which the cable with the lead wires is stored (Fig. 49). One end of the cable is permanently attached to the apparatus; the other end is branched

and fitted with terminals for attaching the electrodes. The terminals are specially marked: red for the right hand, yellow for the left hand, green for the left leg, black for the right leg, and white for the chest.

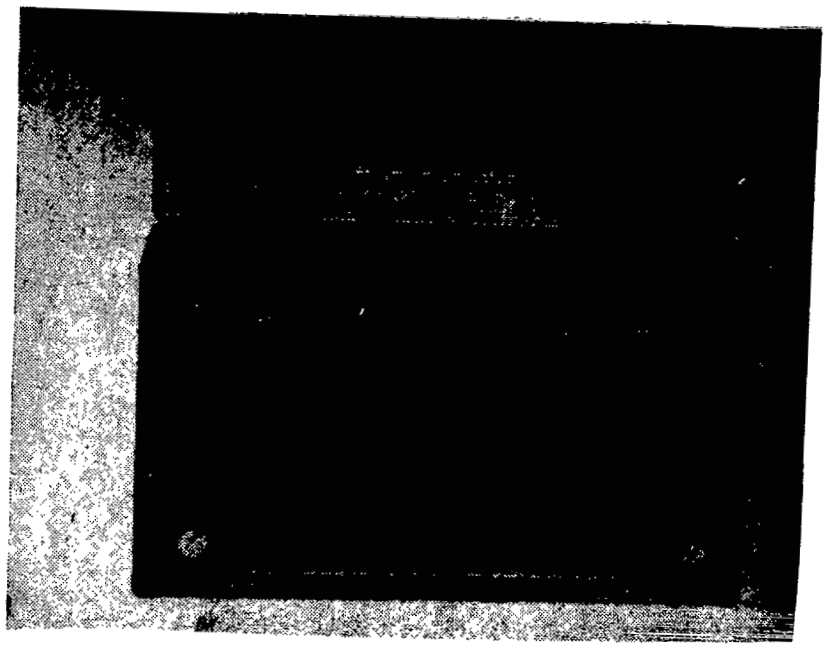


Fig. 47. Overall View of EKP-60 Electrocardiograph.

Fig. 48. Control Panel of EKP-60 Electrocardiograph.

The back of the cabinet is fitted with a special hinged cover, behind which is the battery compartment.

On the control panel (Fig. 48) there are the following controls: top row - knob 1 for the lead switch, lens 2 of the pilot light, toggle switch 3 for charging the battery, toggle switch 4 for turning on the amplifier, and handle 5 for activating the film-transport mechanism (near it is cover 6, which covers the regulator screw for the film-transport speed); bottom row: knob 7 for adjusting the galvanometer, button 8 for the damper, button 9 for the millivoltmeter, knob 10 for adjusting the sensitivity (amplification), window 11 for observing the spot of light, and lid 12 for the film holder, fitted with a dial 13 for measuring the amount of film used. /52

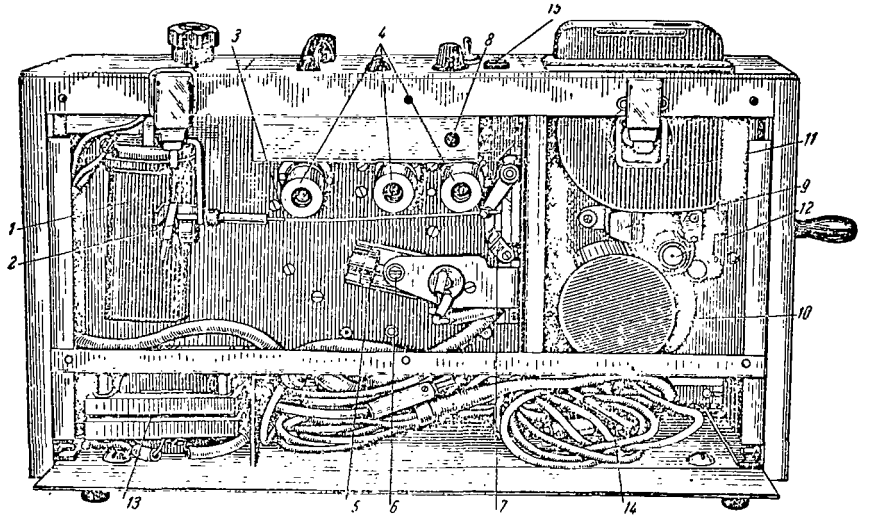


Fig. 49. View of EKP-60 Electrocardiograph With Front of Cabinet Removed.

The front of the cabinet can be removed (by loosening six screws), thus providing access to the parts inside (Fig. 49). At the left is galvanometer 1, with time marker 2 in front of it. Rod 3 runs from the plunger to the time marker. At the bottom is the illuminator 5 (6 is the screw which regulates the angle of the illuminator), and above it is mirror 7, which reflects the light beam onto window 15 so that it can be observed on the control panel of the instrument. At the top, the tubes 4 of the amplifier are visible; above them is a panel with other parts mounted on it, covered by a lid. The right-hand side of the lid has an opening, beneath which is located a potentiometer whose control knob is located below a slit (marked 6 in the diagram) for regulating the amplification. /53

On the right is the film-transport mechanism, consisting of a feed cartridge 11, a transport mechanism (located at the back of the case), a take-up reel 10 with a compressing roller inside, lens 9 which focuses the light beam on the film, and a pressure roller 12. The film is placed in the feed cartridge, then fed between a capstan and the rubber roller of the counter and comes out through a slit. The end of the film is led into the take-up reel and fastened to the reel by a spring.

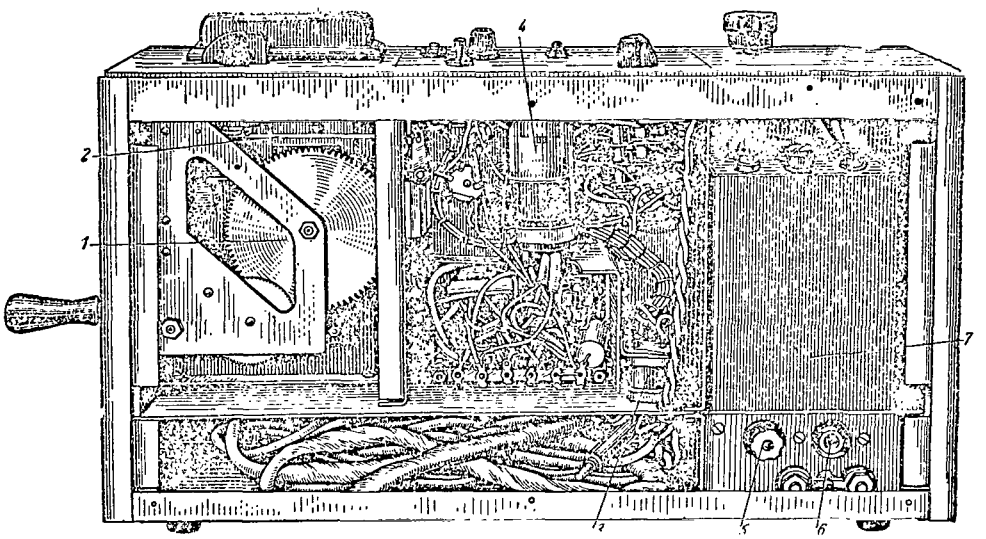


Fig. 50. View of the EKP-60 Electrocardiograph With Rear Cover Removed.

Counter 13 (Fig. 48), mounted on the lid of the film holder, is activated by the moving film. The counter simultaneously indicates the amount of film used and the amount remaining in the feed reel. The film consumption is indicated by fine divisions on a scale relative to a point marked on the lid of the film holder. Each division corresponds to 20 cm of film wound on the take-up reel. The amount of film still remaining in the feed reel is given in meters by a pointer on the counter. When the film is placed in the holder, the indicator is set to show the amount of film and then it moves automatically as the film is used up.

The transport speed of the film is set at the factory between 45-55 mm/sec. To regulate the speed within these limits, it is necessary to open up cover 6 (Fig. 48) with a wrench (provided with the instrument), slacken a locknut, set the adjusting screw with a screw driver to the desired position, and then tighten the locknut.

If the entire back of the cabinet is removed (Fig. 50), the

following parts are visible: at the left, the film-transport mechanism 1 (2 is the rod connecting the plunger to the time marker); in the middle are the parts of the amplifier and adapter 3 (the stabilitron 4 is located at the top; at the right is the battery compartment. /54 The amplifier constitutes a separate unit which can be removed from the apparatus through the control panel. The amplifier section is held in place on the chassis by a special locknut, which can be reached through the compartment for storing the lead cable.

On the right is the battery 7, and below it the fuse and line switch 5 for 127/220 V, in series with a lamp 6 which indicates that the battery is being charged. Immediately behind the fuse, in the lower wall of the battery compartment, is a socket with contacts to receive the line cord when the battery is being charged.

The parts that come with the apparatus, including tubes, a 2NKN-10 battery, lead cable and film holder with reels, include the following:

1. Electrodes: plate-type (for extremities)-4; chest electrode with handle-1; chest electrode with suction cup-1. rubber straps for fastening electrodes in place-4.
2. Line cord for charging batteries.
3. Crank for film-transport mechanism.
4. Tools: wrench, screw driver and combination wrench and screw driver.
5. Spare parts: 1B2P tube-2; 2P2P tube-1; pilot lamp, 3.5 V-0.28 A-1; take-up reel-1.
6. Certificate, technical specifications, and instructions for operation.

Recording of electrocardiograms is done as follows. Before turning on the apparatus, it is necessary to ensure that all knobs on the control panel (Fig. 48) are in the starting position: toggle switch 3 must be in the "operate" position, toggle switch 4 must be in the "off" position, knob 1 of the lead switch must be in position "0", knob 10 of the amplification adjustment must be at the far left, and knob 5 for controlling the film-transport mechanism must be in the "stop" position.

The paper or film is placed on the upper reel in a darkroom, after which the end of the paper is fed through the slit and the lid of the holder is closed. The free end is fed into the take-up reel and pressed between the rollers. The holder is installed on the apparatus. The handle located on the outside of the cover is used to wind up the film-transport mechanism (to do this, the handle must be inserted in the hole on the right-hand side of the cabinet and wound clockwise until it stops). Toggle switch 4 is now set to the "on" position (the pilot light on the instrument panel should light up). After waiting 2-3 min for the tubes to warm up, button 8 of the damper is pressed and the operator must

watch the spot of light on window 11, using corrector 7 to move it to the center of the scale on the glass. Then, by pressing button 9 on the millivoltmeter with knob 10, the sensitivity (amplification) is established, so that the spot of light is deflected about 10 cm by one millivolt.

It is recommended that the wires and switches for the leads be checked. To do this, the lead switch is set to different positions and the terminals of the lead-cable wires are touched to one another, as shown in the table, and a calibrating signal is fed into the circuit. The spot of light observed on the glass should be deflected by the same value each time.

If the deflections are not the same or if the spot does not respond promptly, it is an indication that the wires are damaged.

TABLE 6

Position of the Wire PO	I	II	III	AVR	AVL	AVE	V	CR	CL	CF
	LH	LL	LL	RH	LH	LN	CE	CE	CE	CE
	RH	RH	LH	LL	LL	RH	LH	RH	LH	LL
				LH	RH	LH	RH			
							LL			

The lead with the black RL terminal is less free during this process. /55

The electrodes are then wrapped with thin material moistened with physiological solution, placed on their proper locations, and fastened with rubber straps. During the recording of the electrocardiogram, the patient must lie motionless in the proper position, with his muscles relaxed.

The calibration signal is recorded first. The lead switch is set to zero and the handle of the film-transport mechanism is set to "run"; button 9 is then pressed several times. The mechanism is then stopped and the lead switch is set to the desired position. The button of the damper is pressed and the electrocardiogram is recorded when the spot of light returns to the middle of the scale.

When the entire recording is finished, the apparatus is switched off, the film holder removed, the film strip cut, and the take-up reel removed. The film is removed from the holder and developed in a darkroom. The following is a sample formula for developer to be used with paper or film: in one liter of distilled water at 20° C, dissolve 5 g methol, 10 g hydroquinone, 40 g of sulfite, 34 g of sodium anhydride, and 3 g of potassium bromide. The fixing solution consists of 250 g of hypo in a liter of distilled water.

The batteries must be maintained according to the special instructions provided. The batteries must be charged at least once a month for 6-8 hrs. In order to charge the battery, it must be removed from the compartment and the level of the electrolyte checked (the latter must be 5-10 mm above the plates; if it is lower, distilled water must be added to the battery). The plugs must also be removed from the casing. The plug of the line cord is then inserted into the socket in the compartment and the other end (after checking to be sure that the line fuses are in the proper position) is inserted into the wall socket. On the control panel, the right-hand toggle switch 4 is set to the "off" position while the left-hand toggle switch 3 is set to the "charge" position. The pilot light in the compartment should then light up. Normal charging current of the battery is 2.5 A.

At least two hours after charging is complete, the plugs should be replaced in the casing and the entire battery should be wiped off to remove any drops of electrolyte; it is then returned to its compartment.

In case the apparatus is not used regularly, it should be given an intense charge once a month: 6 hrs at 2.5 A and 6 hrs at 1.25 A. The electrolyte should be changed once a year.

PART 4

ELECTROCARDIOGRAPHS POWERED BY LINE VOLTAGE

§ 1. ELECTROCARDIOGRAPHS WITH PHOTORECORDING

A portable electrocardiograph powered by line voltage was developed by VNIIMIO and has been mass produced since 1957. The first model of this instrument was called the EKPS-1 (a description of which will be found in the Second Edition of this book, 1960). In 1958, the "Red Guard" Factory altered its design somewhat, and it is now being produced under the designation of "single-channel electrocardiograph with photorecording, Model 059", or the EKPS-2 electrocardiograph.

The apparatus consists of the following basic parts: /56

1. A single-channel mechanism which permits recording electrocardiograms without moving the electrodes, from any of three standard, three amplified, and four chest leads.

2. Recordings are made on photosensitive paper for use with oscillographs or on X-ray film, 35 mm wide. The film travels at a rate of 50 or 100 mm/sec.

3. The sensitivity (deviation of the spot of light on the film when a voltage of 1 mV is applied to the input of the amplifier) is 20 mm/mV. The amplitude of the recording is proportional

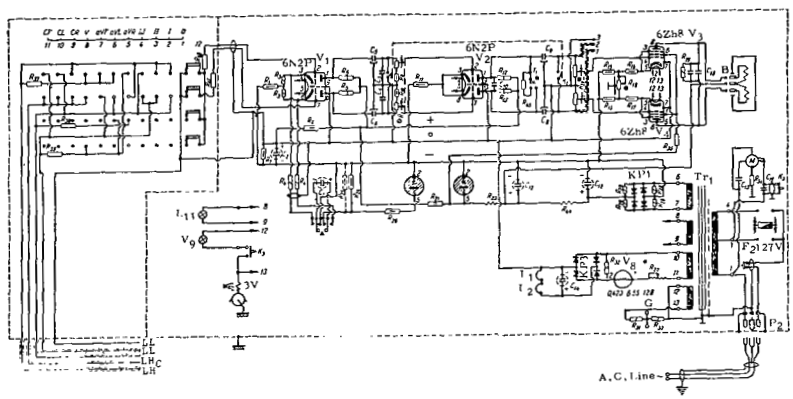


Fig. 51. Schematic Diagram of EKPS-2 Electrocardiograph.

to the input voltage within ± 5% within limits of the amplitude of the recording up to 20 mm and effective input voltages of up to 3 mV.

4. The frequency characteristic is uniform from 0.5 to 100 Hz. The loss at the limiting frequencies is 10-15%.

5. The time constant of the amplifier is 1.5-2.5 sec.

6. The apparatus can be powered by line voltage at a frequency of 50 Hz, 127 or 220 V. The possible deviation is +5 to -10%. Changes in the power-line voltage within these limits cause a change of a maximum of 5% in the sensitivity. In the case of rapid changes in the line voltage within limits of ± 2.5%, the zero line of the recording (with a sensitivity of 10 mm/mV) does not change by more than ± 2 mm/sec.

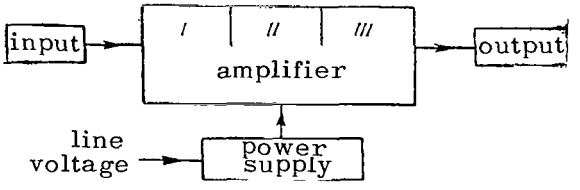


Fig. 52. Block Diagram of Electrocardiograph Powered by Line Voltage (Model EKPS-2).

7. The power consumption is 60 V-A.

8. The time required to establish a working regime of the apparatus after it is connected to the line voltage is at least 10 min.

9. The overall dimensions of the apparatus are 240 × 400 × 390 mm. It weighs 16 kg.

The apparatus consists of an input section, amplifier, and recording section.

The input section contains electrodes wnich are applied to the patient, a cable with wires for connecting the electrodes to the apparatus and the commutator (called the lead switch). The wires from the electrodes are marked as follows: right hand (RH), red; left hand (LH), yellow; left leg (LL), green; chest (C), black; right leg (RL), brown. The lead switch permits only two electrodes at a time to be connected to the input of the amplifier; the potential between these electrodes is recorded. The lead switch has 11 positions. In the zero position, the electrodes are disconnected from the input of the amplifier, which is then shorted out and connected to the chassis of the apparatus (grounded). Under these conditions, the position of the zero line in the recording can be checked, and the regulation of the required sensitivity can be made with the aid of a calibrating signal. The remaining 10 positions of the switch are used when making recordings from the patient and correspond to the leads described above.

The schematic diagram of the electrocardiograph is shown in Figure 51, while the block diagram is shown in Figure 52. The

amplifier consists of a two-stage differential circuit having three cascades with resistance-capacitance coupling and a power supply. The first two cascades use dual triodes 6N2P to amplify the voltage, while the third consists of two 6Zh8 pentodes, which amplify power. A vibrating galvanometer (vibrator) is connected to the output of the amplifier.

As we have mentioned previously, the differential amplifier considerably reduces the influence of stray currents. Attenuation of the amplification of the cophasal potentials which are fed into the amplifier is also achieved by means of a powerful negative feed-/57 back to the grids in the first and second cascades. In addition, a voltage divider is connected between the grids of the triodes in the second stage, which can be used to balance the anode currents of the triodes.

Let us examine briefly the path of an input signal through the amplifier. The voltage from some pair of electrodes which are placed on the patient pass through the lead switch contacts and the leakage resistors 40 and 41; they then travel through shielded leads to the grids of the triodes in tube V_1 in the first stage. A high-ohmage resistance 1, which forms the feedback circuit to the grids, is connected to the common circuit of the tube cathodes.

The voltage amplified in the first tube travels to the grids of tube V_2 in the second stage through coupling capacitors 5 and 6 and variable potentiometer 2. This stage works with a strongly negative feedback, produced by high-ohmage resistor 11 which is connected in a common circuit with the tube cathodes. In conjunction with the high negative bias which is formed on the grids due to the constant component of the anode current, another, independent, positive bias is formed on the grids of the tubes of all three stages, and is formed by means of a voltage divider across resistances 7 and 8 which are connected to the power supply. the positive bias is formed across resistance 7, which is used to suppress the feedback through the alternating component shunted by capacitor 2, and is then fed to the zero lead which connects all the elements which are used for shielding in the amplifier. It connects these elements to the chassis and the field electrode on the patient (the electrode located on the right leg).

Hence, the potential on the chassis of the apparatus is approximately 30 V higher than the potential of the negative side of the power supply to which the cathodes of the tubes are connected. This means that the chassis of the apparatus must be grounded during operation.

From the zero lead, this bias passes to the grids of the first tube through electrodes used for recording and resistors 40 and 41. The bias is applied to the grids of the second tube through the center tap of the voltage divider formed by resistors 9 and 10 and the double variable resistor 2. Resistor 2 can be used to

balance the anode currents of the triodes in the second stage and thus balance the amplification of the amplifier arm with respect to the cophasal signal.

From the anodes of the tube in the second stage, the amplified voltage passes through the double potentiometer 14 to the grids of tubes V_3 and V_4 in the output stage. Potentiometer 14 is used to set the sensitivity (amplification), which must be done for each recording. The handle of potentiometer 14 is mounted on the control panel. The potentiometer has a linear characteristic which ensures a direct relationship between the sensitivity and the degree of deflection of the handle of the potentiometer. From the tap of potentiometer 14, the positive independent bias from the zero lead passes to the grid of the tube. From the end terminals of potentiometer 14, shielded wires run to the control panel to permit connection of an oscilloscope, so that the electrocardiograms being recorded can be seen on the face of the cathode ray tube.

The cathode circuits of tubes V_3 and V_4 contain resistors 15-17 of the feedback circuit, and between them is a variable resistor 18 which can be used to regulate the value of the negative feedback in the third stage, and (consequently) the sensitivity or amplification of the entire amplifier. Resistor 18 is mounted "below the slit" and is adjusted when the amplifier is assembled.

To reduce the sensitivity of the apparatus by approximately a factor of two, as is usually necessary when recording from the chest leads, a toggle switch T_1 is provided which shunts the output /58 circuit from the second stage across resistor 45 (this toggle switch is located on the control panel).

The anode circuit of tubes V_3 and V_4 contains the coils of vibrator B. The supply voltage is applied to the center tap of the coils. Between the anodes of the tubes is a capacitor 18 which is shunted by resistor 19. Together with capacitors 3 and 4, which are connected between the anodes of the tubes in the first stage, it serves to improve the frequency characteristic of the amplifier (lowering it in the high-frequency range).

The screen grids of tubes V_3 and V_4 are powered through resistor 36, which shield the grids which are connected directly to the cathodes.

In the output circuits of the first and second stages, there are the contacts of the damper button K_1. When the button is pressed, the circuit between capacitors 8 and 9 is closed first, and then the circuit between capacitors 5 and 6.

The power supply contains a power transformer Tr_1, which can be connected to a line voltage of 127 or 220 V. The proper sections of the primary winding of the transformer are connected by inserting fuses F_1 or F_2 into the proper sockets. An electric motor M

(Model 887, synchronous, 1 W, 127 V) is connected to the primary winding for 127 V. The power leads to the motor include capacitor 13, resistor 34, and push button K_3. The primary winding is shielded, and the shield together with the core of the transformer and lead 12 from one of the heater supply windings are grounded by the third prong in the power cord.

The secondary winding of the transformer (190 V) is connected to a semiconductor rectifier consisting of KP-1 diodes (D7Zh), with a ripple filter and stabilitrons, which provide the power for the anode circuits in the amplifier. The anodes of tubes V_3 and V_4 of the final stage of the amplifier are connected through a filter (capacitor 12 and resistor 44), while the screen grids of tubes V_3 and V_4 are connected after the first stabilitron SG-4S (V_6). The anode circuits of the first and second stages are powered by a doubly stabilized voltage and are connected after stabilitron SG-3S (V_5).

The voltage now passes through a voltage divider to resistors 26-24 (resistor 25 is used for regulating the value of the signal) and then passes to capacitor 1 for the calibrated signal. When button K_2 is released, capacitor 1 is connected to a constant voltage of 15-20 V. When the button is pressed, the capacitor begins to discharge through resistors 3 and 4. As a result, resistors 3, which are connected to the cathode circuit of the first tube, are connected to a voltage of 1 mV, which is fed to the grids of the triodes. As the capacitor discharges, this voltage falls, although very slowly (time constant of the circuit is about 130 sec). Therefore, an estimate of the height of the calibrating signal must be made on the basis of the leading edge.

The heaters of tubes V_1 and V_2 are powered by current from a separate winding on the transformer (terminals 10-11, 22 V), stabilized by ballast tube V_8 through a transistorized rectifier KP-3 (D7D) with a filter capacitor 14 of high value. A variable resistor 27 is connected in series with the ballast tube (type 0.425-B-5.5-12). With nominal voltage in the circuit, the voltage across the ballast tube is 10.8-11.2 V. The remaining 10 V go to the heater filaments of tubes V_1 and V_2 which are connected in series.

The tubes in the final stage are heated from the windings of the transformer (terminals 12-13, terminal 12 grounded), from which voltage also passes to tube V_0 (MN-14; 6.3 V, 0.28 A) in the time marker, the winding of the sound indicator in the paper transport system, and the voltage divider consisting of resistors 31 and 33 with prongs G. The voltage between prongs G and the chassis is about 0.1 V. This is used to balance the arm of the amplifier by means /59 of a variable resistor 2 (see above).

Lamp L_{11} (MN-25, 2.3 V, 1.5 A) is powered by a separate winding (terminals 8 and 9, voltage of 2.3 V).

Capacitor Data

1	KÉ-2, 20/50 M	12	KE-2, 400/20 M
2	KE-2, 30/100 M	13	MBGP-2, 600-B-2-P
3-4	KSO-2, 500-A-390-P	14	KEG-2, 30/100 M
5-9	KBG-MN-2-200-1-P	19	KBG, I-600-0.3-111
10	KBG-I-200-4700-P	18	KBG, I-200-0.1-111

Resistor Data

1	MLT-1, 360 kΩ 1-A	21	MLT-2, 5.1 kΩ 1-A
2	SP-Sh-OS-520, A 0.5 W 1 MΩ / A 1.0 W 1 MΩ	23	PE-7.5, 2 kΩ ± 5%
3	MLT-0.5, 100Ω 1-A	24	MLT-0.5, 39 kΩ 1-A
4	MLT-0.5, 1300 kΩ 1-A	25	MLT-0.5, 75 kΩ 1-A adj.
5-6	MLT-1, 560 kΩ 1-A	26	MLT-0.5, 200 kΩ 1-A
7	MLT-0.5, 75 kΩ 1-A	27	PEV-10x, 10Ω ± 10%
8	MLT-0.5, 270 kΩ 1-A	28	MLY-1, 100 kΩ 1-A
9-10	MLT-0.5, 2700 kΩ 1-A	31	MLT-0.5, 3 kΩ 110-A
11	MLT-1, 360 kΩ 1-A	32	MLT-2, 150 Ω 1-A
12-13	MLT-1, 560 kΩ 1-A	33	VS-0.5-a, 51 Ω 10%-B
14	SP-Sh-OS-520, A 0.5 W 3.3 MΩ / A 1.0 W 3.3 MΩ	34	MLT-1, 100 kΩ 1-A
15	MLT-0.5, 5.6 kΩ 1-A	36	MLT-0.5, 10 kΩ 1-A
16-17	MLT-0.5, 470 Ω 1-A	37-39	MLT-0.5, 30 kΩ 1-B
18	Sp10S-3, 12 gr1UA, 2 W 10 kΩ	40-41	MLT-0.5, 4.7 kΩ 11-B
19	MLT-1.0, 100 kΩ 1-A	44	PE-7.5, 1.5 kΩ ± 5%
		45	MLT-0.5, {390 kΩ 1=A / 470 kΩ 1=A adj. / 560 kΩ 1=A}

It should be mentioned that the EKPS-2 instruments of earlier manufacture have several insignificant differences with regard to the schematic diagram; e.g., there are no leads for connecting an oscilloscope, there is a separate switch for the line voltage (127/220 V), the transformer windings for heating the tubes and the pilot lights are common, etc.

The recording system of the apparatus consists of a vibrator, time marker, illuminator, several auxiliary devices, and the film-transport mechanism.

Figure 53 shows a combined diagram of the optical and mechanical systems in the recording section of the apparatus. The optical section contains an illuminator ILL, the light from which is reflected by mirror M_2 to mirror M_1 on vibrator B. After being reflected from the mirror, the light strikes the main cylindrical plano-convex lens PL and is focused on photosensitive paper. A portion of the light from mirror M_1 of the galvanometer is deflected by mirror M_3 and passes through lens L_1, which focuses it in the form of a spot on the ground glass MS for observation. Lens L_1 is mounted in a spring-loaded support and can be set to vibrating by pressing and releasing a button located on the control panel. This

spreads the spot of light out into a line and makes it possible to detect even very small extraneous signals.

Near the vibrator is the time marker TM. This consists of an illuminator I_2 and a disk DN with notches in its edge (see the lower part of the diagram in Fig. 53). When the notches in the disk coincide with the opening in the illuminator, light in the form of short pulses strikes lens PL which focuses it in the form of a line extending over the entire width of the paper. There are 10 notches in the disk, with every fifth notch being wider. The /60
disk is driven by a flexible coupling from the film-transport mechanism at a speed of 300 rpm, so that markings are obtained every 0.02 sec. and the wider markings appear every 0.1 sec.

The film-transport mechanism consists of an electric motor EM with a built-in gear reduction connected by a flexible sleeve FS to the gear box and sprocketed drum DS, which moves the paper or film, and two holders: the feed FC (below) and the take-up TC

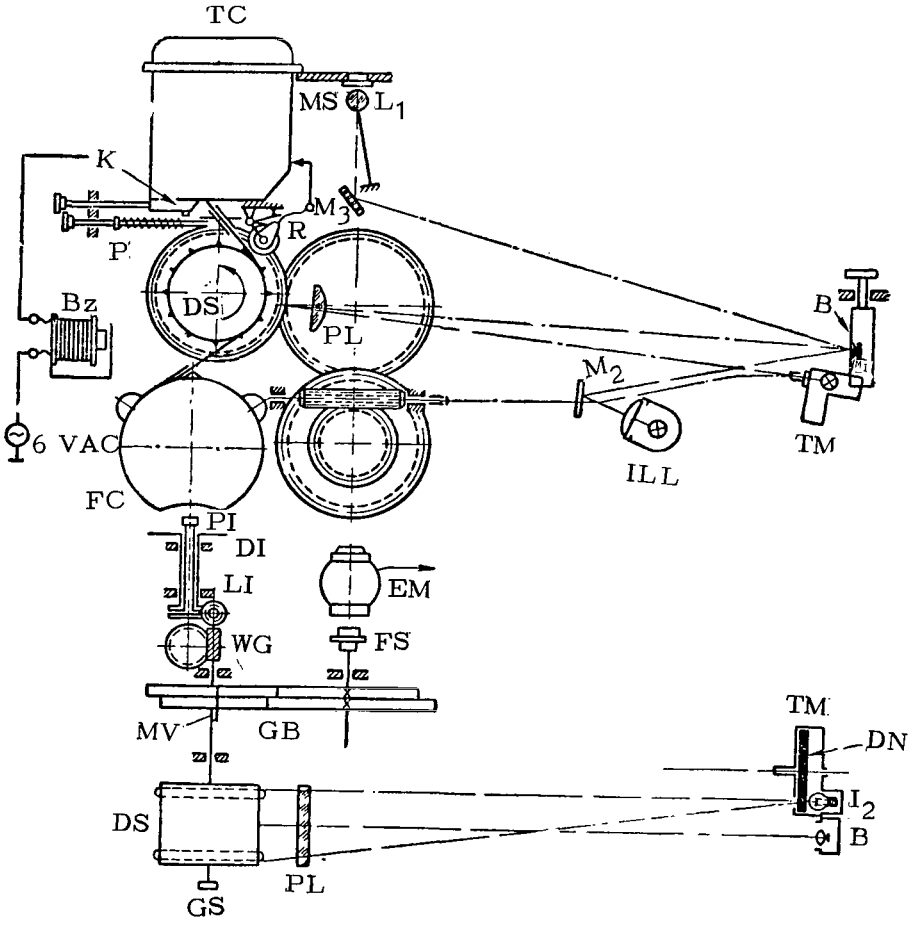


Fig. 53. Optical and Mechanical Parts of EKPS-2 Electrocadriograph.

(above), respectively. The capacity of the holders is as follows: feed container, 20 m; take-up container, 6-8 m of paper or film.

Sprocketed drum DS is mounted on an axle linked to the gear box GB by a movable knob MB which can be moved by gear shift knob GS. The movable shaft has three positions: (a) with the gear shift handle pulled all the way out, the film transport mechanism is disconnected; (b) with the gear shift handle pushed all the way in, the film speed is 50 mm/sec; (c) with the gear shift knob pushed in only as far as the circular slot, the film speed is 100 mm/sec. The film-transport mechanism is set in motion by pressing the starter /61 button for the electric motor, located on the control panel. (The speed should not be changed while the motor is running). The film which is held against the sprocketed drum DS by rollers R is electrically insulated from the chassis of the apparatus; it moves from the feed container FC to the take-up container TC. At the same time that the film transport mechanism is turned on, the lamp in the time marker is switched on and its disk begins to rotate. The paper or film which moves between roller R and the drum interrupts the electrical circuit to an audible signal (buzzer) Bz, which is connected to roller R. If all of the paper runs through, the roller contacts the surface of the drum and the circuit to the buzzer is closed.

An indicator LI is mounted on the axle of the film-transport mechanism to show the amount of paper consumed. It consists of a

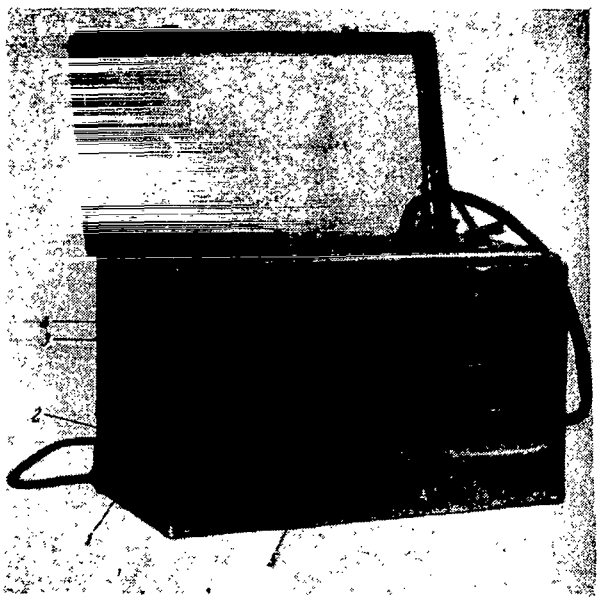


Fig. 54. General View of EKPS-2 Electrocardiograph.

worm gear WG, which is connected to two gears having different numbers of teeth. One gear is connected to disk DI, located on the control panel, while the second is connected to pointer PI which rotates relative to the disk. The teeth of the gears are set so that the pointer travels almost completely around the disk when 20 m of paper have passed through. The disk is inscribed with a scale whose divisions indicate 0.5 m of travel of the paper. After filling the container and mounting it in place, the pointer on the indicater PI, which is connected to the gear by a friction drive, must be set to the zero position.

The film-transport mechanism is also fitted with a knife K for cutting the paper when rolling it up into the take-up container and a punch P for making markings on the strip. The buttons for operating the knife and punch are located on the left side of the cabinet. A special lip on the take-up container allows the container to be removed only when the knife button is pressed, i.e., only when the strip has been cut.

The following is a general description of the apparatus. An /62
overall view is shown in Figure 54. The apparatus is mounted in a metal cabinet with a hinged lid. Within the cabinet, the parts are mounted on a chassis, which is covered on top by a control panel.

On the left side of the cabinet, in the lower rear corner, there is a socket 1 for connecting the line cord, and below it a socket 2 for connecting the ground wire. In the lower front corner

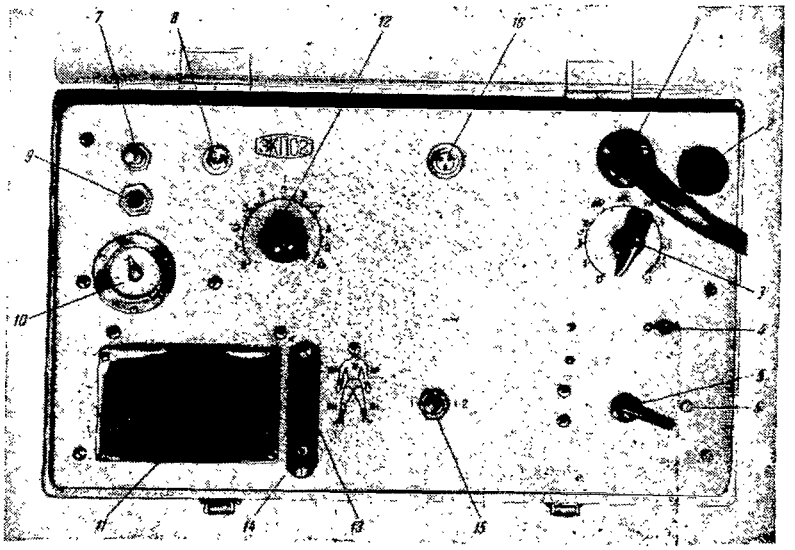


Fig. 55. Control Panel of EKPS-2 Electrocardiograph.

are the buttons for the knife 4 and punch 3. On the front of the cabinet is a closed lid 4 with a wide slit, which makes it possible to gain access to the take-up container and the knob for changing the film-transport speed. The fuses, which simultaneously serve for changing the input voltage, are located inside the cabinet on the left-hand side. It is necessary to open the cover on the bottom of the cabinet to reach them.

On the right-hand side of the cabinet, at the bottom, there is an opening closed with a metal lid. The latter can be opened with the aid of a screw driver for adjusting the resistance (marked R_2 in the circuit diagram) to balance the amplifier.

A general view of the control panel is shown in Figure 55. In the upper right corner is the input 1 for the cable containing the wires from the electrodes. Near it is a knob 2 which is used for supporting the panel when the apparatus is being removed from the cabinet; below this is knob 3 of the lead switch and below that knob 5 for adjusting the vibrator, which is used to set the position of the zero line on the recording.

Near the right-hand edge of the panel are the following: button 4 for the calibrating signal and head 6 of the screw which is used to adjust the angle of the vibrator. In the upper left corner is a line switch 7 and a button 8 for the damper. Below the switch is a button 9 for activating the film-transport mechanism, and below that the indicator 10 to show the amount of film consumed, as well /63 as the lid 11 for the take-up container.

Along the upper edge of the panel, there are the following: a socket 16 for attaching an oscilloscope, at the middle left, a knob 12 connected to a potentiometer for adjusting the sensitivity (amplification), and in the lower part of the panel, on a line with the lid for the take-up container, a window 13 for observing the spot of light. In this area are also the button 14 for spreading out the spot and a toggle switch 15 for reducing the sensitivity of the amplifier by a factor of 2.

The design of the vibrator is shown schematically in Figure 56. The vibrator is flat and consists of a steel frame 0, in the lower part of which is located a permanent magnet 1 with pole pieces 2 and coils 3 wound on the latter. The wires from the coils are connected to contacts 9 by which the vibrator is linked to the amplifier. Strip 4 is located between the pole pieces and serves as an armature. To the end of this strip is fastened the lower end of a wire 5 carrying mirror 6. The vibrator wire is a narrow, thin, perforated strip of phosphor bronze, with a preliminary twist in it. The upper end of the wire is fastened to a mount 8 on a flat, flexible support. The position of the mount, and consequently the stress on the wire, is regulated by adjusting support 10 with knob 13 fitted with spiral spring 11. The upper end of rod 13, which projects through the control panel, is fitted with a knob which is

used to adjust the position of the spot of light (zero line) on the recording strip. The wire passes through a damper 7 which is a ring filled with viscous fluid.

The frame of the vibrator is attached to the control panel by a bracket 12 and screws 14 (one of which projects through the control panel) and is covered by a housing which slipped over it from below. The method of operation of this vibrator is similar to that of the one in the EKP-60 apparatus described above (see Fig. 46, b), except that this one has two coils which are connected differentially to the anode circuits of the tubes in the output stage. As we have mentioned earlier, the variations in the anode currents in these tubes, which arise as a result of amplified voltage, are in opposite phase. Consequently, oscillation of the magnetic flux in the poles of the vibrator will take place when the phases are in opposition: if the magnetic flux increases in the upper pole to a certain value $\Delta\Phi$, then it will decrease by the same value $\Delta\Phi$ in the lower pole. Consequently, the pole on the armature toward the upper pole will increase and the pole toward the lower pole will decrease. The armature will oscillate between the pole of the vibrator, depending on the frequency and shape of the oscillations of the magnetic flux formed by the anode currents of the tubes in the output stage. Actually, they will reflect the oscillations in the voltage received at the amplifier input. The oscillations of the armature, causing the previously twisted wire to stretch or relax, will impart similar oscillations to the mirror, so that the latter will revolve around the vertical axis of the wire; the movements of the mirror can be recorded on the strip by means of the optical system.

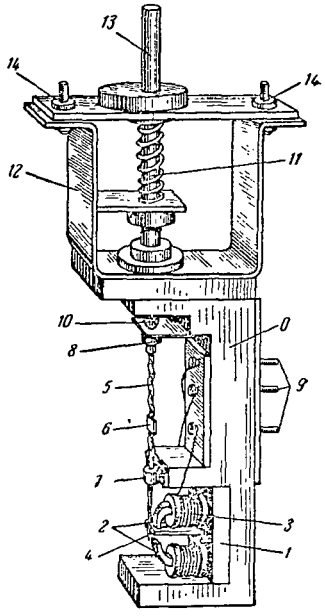


Fig. 56. Diagram of Vibrator Used in EKPS-2 Electrocardiographs.

Some details of the vibrator are the following: /64

(a) Nominal current of magnetization equals 7 mA;
(b) Resistance of each coil to direct current: 1100-1300 Ω;
(c) Sensitivity at a beam length of 25 cm, from 40 to 80 mm/mA.
(d) Sensitivity to the cophasal component of alternating current, under the same conditions, no more than 4 mm/mA;
(e) Residual drift of the beam, no more than 5%;
(f) Frequency of natural oscillations, at least 700 Hz.

Figure 57 and 58 show the apparatus with the cover removed. From the front (Fig. 57) we can see the following: illuminator 1, the light from which passes via mirror 2 (located behind the partition) to the mirror on the vibrator 11. Behind the vibrator, we can see the time marker 12 and the flexible coupling 3 which

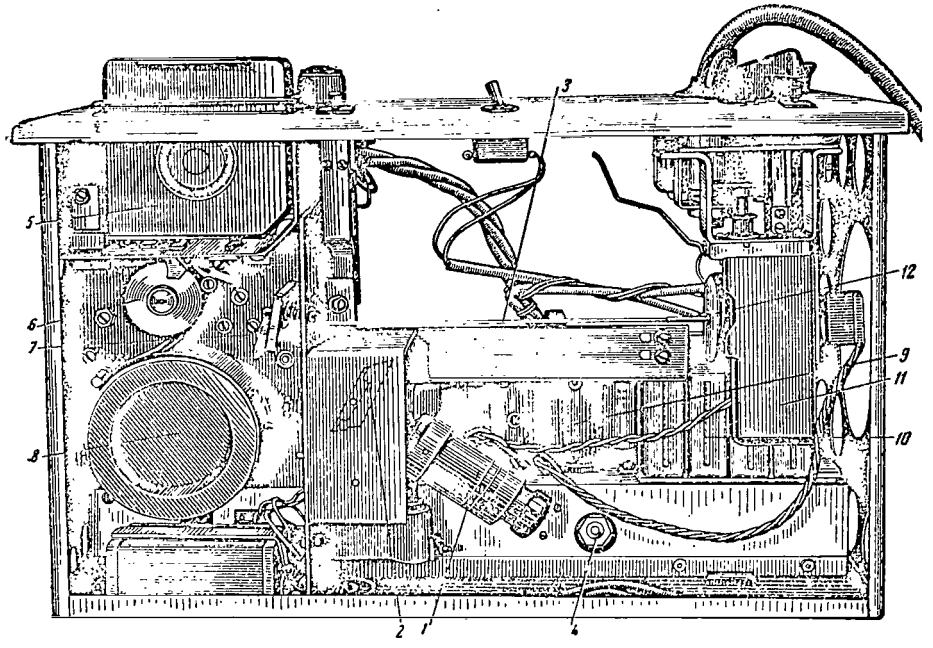


Fig. 57. General View of EKPS-2 Electrocardiograph, With Cover Removed, as Seen From the Front.

runs to it. On the back of the chassis is knob 4 of the resistor (marked R_{18} in the diagram) for regulating the total sensitivity of the amplifier. On the left is the film-transport mechanism: the feed container 5, sprocketed drum 6, principal lens 7, and take-up container 8. In back of the recess for the take-up container there is a socket (marked G in the diagram) for the voltage divider used for balancing the amplifier. In the middle of the chassis, are the tubes 9 of the amplifier and capacitors 10 at the right.

From the rear (Fig. 58) the following can be seen: at the upper left, the unit 1 for switching leads, and near it the millivolt capacitor, and below that (on the chassis) the tubes and other parts of the amplifier. At the left front are tubes 2 and 3 of the first and second stages, and behind them capacitors 4 as well as electrolytics 5 and stabilitrons 7; behind the stabilitrons are the tubes 6 of the output stage. The end tube 8 is the ballast tube. On the right are the transformer 8 and above it, electric motor 9.

The apparatus comes complete with all tubes as well as the following supplies which are packed in a rubberized cloth bag: (1) a shielded power cord, 3 m long with an extension; (2) wire for grounding, 8 m long with a clamp; (3) electrodes for extremities, 4; for the chest, 1; (4) rubber straps for attaching electrodes, 4; (5) fuses: 0.25 A, 2; 0.5 A, 2; (6) spare bulbs for time marker, 2; for illuminator, 3; (7) screw driver; (8) spare feed and take-up containers; (9) description and instructions for the apparatus. /65

Setting up the apparatus for recording electrocardiograms is performed as follows. The chassis and the bed on which the patient whose electrocardiogram is to be taken is lying, if it is made of metal, must be carefully grounded; this is not necessary for the patient himself, however. To do this, the parts of the metal bed with which he is likely to come in contact must be insulated (e.g., by wrapping them with cloth), and the apparatus must be placed beyond the reach of the patient. All the lids of the apparatus should be in place to avoid any danger.

Before plugging the apparatus into the wall, it is necessary to check that the fuses are in the proper position depending on the voltage available; the sensitivity control must be set to the proper position, with the lead switch in the zero position and the line switch in the "off" position. The power cord is then plugged into the apparatus, the grounding wire is either plugged into the

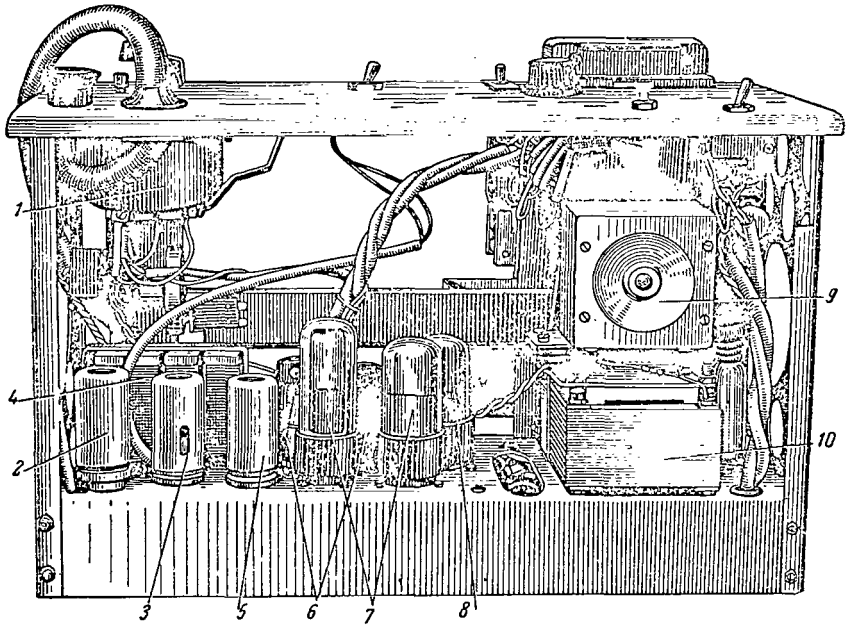


Fig. 58. View of the EKPS-2 Electrocardiograph With Covers Removed, as Viewed from the Rear.

socket provided on the cord plug or into the socket on the chassis; the other end is then wrapped around a water pipe or a radiator, after which the line cord can be plugged into the wall socket.

The line switch 7 is turned on (Fig. 54) and at least five minutes must elapse before the tubes have reached their operating temperature. This time can be used for applying the electrodes and connecting the wires from the apparatus to them.

When this time is over, knob 5 of the vibrator adjustment (Fig./66 55) can be moved to set the position of the zero line in the middle of window 13; by pressing button 4 for the calibrating signal, and moving knob 12, the sensitivity for the deviation of the zero line can be set to 10 mm (this usually amounts to the fourth or fifth division on the scale beneath knob 3). This corresponds to a sensitivity of 10 mm/mV.

Now, by pressing button 8 on the damper, the lead switch is turned to the first position. When the button is released, oscillations of the spot of light can be seen on window 13, which are produced by stray currents. (Button 14 should be pressed and released several times until the proper setting is obtained). Electrical devices, table lamps, and wires in the wall can produce considerable interference if they are near the patient. To get rid of these extraneous currents, it is necessary to disconnect the troublesome devices from the line; if this is impossible, the patient must be moved to some other location. After checking to be sure that the supply container is full and knob 3 has been set to the zero position, the apparatus is ready for recording.

The following must be done to record electrocardiograms:

1. Press the damper button, set the lead switch to zero. If the zero line wanders while the damper button is being pressed, press it again. If it is impossible to make the zero line remain stable by using the button, it is necessary to check the quality of the contact of the electrodes. It may be that they are fastened loosely or that the paste has dried out.

2. When the button is released, the damping can be adjusted by using the knob to set the desired position of the zero line.

3. Pressing button 9 turns on the film-transport mechanism.

4. After recording is over, the damper button must be pressed and the lead switch returns to the zero position.

Whenever the lead switch is changed from one setting to another, the damper button must be pressed. After switching, the button must be pressed and released several times until the zero line reaches a steady position. If it is necessary to do so during the recording, the damper button can be fixed in the depressed position by

turning it in this position a quarter turn in the socket.

During recording, it is necessary to watch the paper supply in the take-up container by monitoring indicator 10. Before removing the take-up container, it is necessary to press button 4 to cut the paper (Fig. 54). This button must be kept pressed while removing the container, or the latter will not come loose.

To reduce the intensity of the light from the principal lens 7 (Fig. 57) it is fitted with an adjustable diaphragm.

When the apparatus is connected to the line for the first time (after purchasing it) it should be allowed to dry out before hand for about one day with all of the covers removed, with an ambient temperature of 15-20°. The factory ships the apparatus set for 220 V.

While using the apparatus, it is necessary to check the calibration of the voltage and the sensitivity of recording at least twice a year. When replacing the tubes in the amplifier or the ballast tube, or when there is an excess of stray currents which cause smearing of the zero line of the recording, it is necessary to make the arms of the amplifier symmetrical by using the variable resistor 2 and the voltage taken from socket G of the amplifier. After installing or removing any parts, it is necessary to regulate the sensitivity of the amplifier. This is done with adjustable resistor 18. It may also be necessary to check and regulate the action of the ballast tube, the time marker system, the optical /67 system, etc. Instructions on how to do these things are contained in the manual provided with the instrument.

§ 2. PHONOELECTROCARDIOGRAPH

The type FEKP-2 phonoelectrocardiograph was devised by VNIIMIO and is being produced by the "Red Guard" Factory (Model 052). The instrument is an EKPS-2 electrocardiograph with a second channel for recording phonocardiograms, or diagrams of heart sounds. Simultaneous recording of these curves is made on perforated photosensitive paper for use with oscillographs (35 mm wide). The principal data on the electrocardiographic part of the apparatus are exactly the same as those described above (see § 1). In addition, there are certain details regarding the phonocardiographic channel which should be discussed.

(1) The microphone is a dynamic coil type. The output level of sound transmission at a frequency of 1000 Hz is at least -72 db (250 μV/bar). The DC resistance of the coil is 160 Ω.

(2) The frequency characteristics and sensitivity of the channel are listed in Table 7.

TABLE 7

Symbol	Name	Nominal Frequency Hz	Transconductance of the Characteristic db/octave	Maximum Sensitivity mm/bar
A	Auscultative	140±25	14-19	30
L	Low frequency	85±10	7-10	3
M_1	Medium frequency No. 1	70±15	14-19	15
M_2	Medium frequency No. 2	140±25	20-28	40
H	High frequency No. 1	250±50	20-28	100

(3) The double amplitude of the natural channel noise, recorded when a standard block with a resistance of 180 Ω is connected to the input of the amplifier, cannot exceed the following values at maximum sensitivity (as shown in the table): with characteristic A, 0.5 mm; L, 0.25 mm; M_1, 0.25 mm; M_2, 0.5 mm; H_1, 1 mm.

(4) A change in the power supply voltage within limits of +5% and -10% causes a change in the sensitivity of the channel by no more than 15%.

In addition to being recorded on photosensitive paper, the photocardiogram can also (a) be observed on the screen of an oscilloscope connected to the instrument, (b) be projected on the screen of a vector electrocardioscope VEKS-01, (c) be recorded on magnetic tape by the MAG-8 M tape recorder. It can also be heard by turning on the speaker of the tape recorder while monitoring the input signal.

Figure 59 shows a block diagram of the electrical part of the apparatus. As we have pointed out earlier, the apparatus has two independent amplification channels which terminate in independent vibrators B writing on a common strip chart. Microphone M is connected to the input of the phonographic channel, while the electrodes which run through lead switch LS are connected to the input of the electrographic channel.

The schematic diagram of the electrocardiographic channel is exactly the same as that shown in Figure 52, except for the fact that the winding of the power transformer provides 24 V from terminals 8 and 9 for powering the amplifier of the phonographic channel. The light (L_{11}) of the illuminator is powered by a separate winding with terminals 14 and 15, providing a voltage of 2.3 V. /68

The amplifier for the phonographic channel consists of semiconductor triodes in five stages, combined in a circuit with a grounded emitter and a resistance-capacitance coupling. The schematic diagram of one stage of this amplifier is shown in Figure 60.

The voltage to be amplified passes through capacitor 1 to the base of the emitter. The base circuit also is biased by a voltage divider consisting of resistances 2 and 3. The emitter circuit contains a resistance 1 which is shunted by capacitor 2, to produce a negative feedback in the constant component of the collector current. The collector circuit contains a loading resistor R_k. The amplified voltage is fed from the collector to a blocking capacitor C_c. Under conditions of stable operation, the power supply of the amplifier is connected with the positive pole to the base.

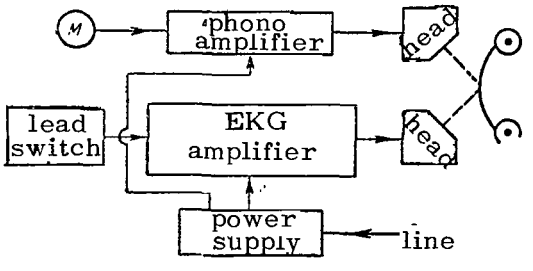


Fig. 59. Block Diagram of Phono-electrocardiograph, FEKP-2.

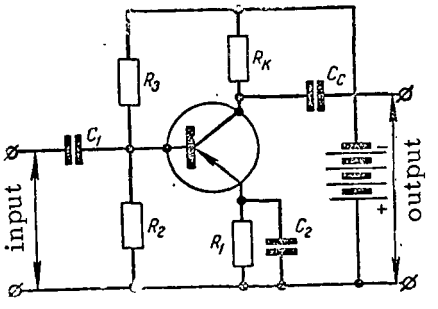


Fig. 60. Schematic Diagram of Amplifier Using Semiconductor Triodes.

The schematic diagram of the sound channel is shown in Figure 61. The amplifier consists of PIZA transistors and has five stages, with the final stage being a push-pull. The change in frequency characteristics is accomplished by varying the negative feedback in the stages with the alternating component of the collector current; to do this, the capacitors and resistors in the emitter circuits of the triodes are switched. All switchings are accomplished by means of switch S_1. The number of operating stages of the amplifier changes when the frequency characteristics change. With the frequency characteristic of L, amplification is produced by three stages, by four stages for M_1, and by all five for the others. The amplifier also has provision for regulating the sensitivity (amplification) within the limits of each characteristic. This is done in stages with switch S_2 and continuously with potentiometer 38.

The voltage generated in the coil of the microphone passes through the connection on the control panel (contacts 1 and 2) to the input resistor 1 of the first triode PP_1. The middle contact of the microphone is connected to the common grounded positive lead of the amplifier. The collector circuit of the triode contains resistors 21 and 22 which can be varied to achieve a step-wise regulation of amplification (in a ratio of 1 to 2.5).

The voltage amplified in the first triode, depending on the position of switch S_2, can either be fed to the second triode PP_2,

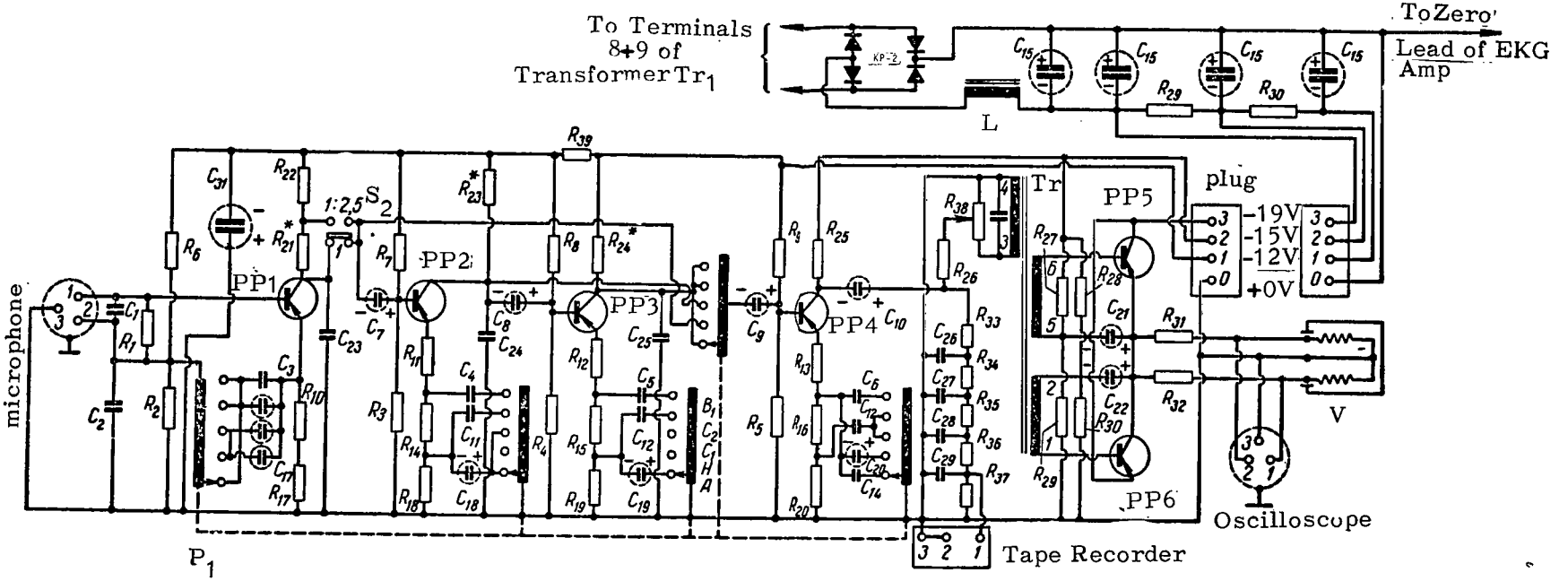


Fig. 61. Schematic Diagram of Sound Channel in the FEKP-2 Instrument.

or directly to the fourth triode PP_4. To reach the second triode PP_2, it must pass through blocking capacitor 7. The voltage amplified in the second triode passes to the base of the third triode /69
PP_3 through blocking capacitor 8, or (if it skips triode PP_3) it passes through the contacts of switch S_1 and capacitor 9 to the fourth triode PP_4. From the collector of the fourth triode PP_4, the amplified voltage passes through coupling capacitor 10 and variable resistor 38 to the winding of the intermediate transformer in the push-pull output stage.

From the voltage divider (resistors 33-37, capacitors 21-29) at the output of the fourth stage, wires run to the terminals 1, 2, and 3 for connecting the tape recorder.

The coils of vibrator V, similar to the vibrator in the electrocardiographic channel, are connected to the emitter leads of triodes PP_5 and PP_6 in the output stage, in series with resistors 31 and 32. The leads for the oscilloscope are connected in parallel with the coils. The power wires to the amplifier are connected to the power supply through a special panel P. Power is supplied by a rectifier (KP-2) consisting of germanium diodes, connected to the terminals 8 and 9 or the power transformer Tr_1 (see Fig. 51). The rectified voltage is filtered by a choke L, capacitors 15, and resistors 29 and 30. As shown in the diagram in Figure 61, power for the amplifier stages is tapped from various points in the filter. The positive lead of the power source runs to the audio channel of the amplifier and is also connected to the common grounded zero lead of the amplifier for the EKG channel.

Resistor Data

1	MLT-0.5, 6.8 kΩ IIIA	25	MLT-0.5, 8.2 kΩ IIB
2-5	MLT-0.5, 36 kΩ IA	26	MLT-0.5, 2.7 kΩ IIB
6-9	MLT-0.5, 24 kΩ IA	27-28	MLT-0.5, 12 kΩ IB
10-13	MLT-0.5, 100 Ω IB	29-30	MLT-0.5, 51 kΩ IB
14-16	MLT-0.5, 270 Ω IB	31-32	MLT-0.5, 3 kΩ IB
17-20	MLT-0.5, 10 kΩ IIA	33-36	MLT-0.5, 4.7 kΩ IB
21	MLT-0.5, 5.1 kΩ IA	37	MLT-0.5, 560 Ω IIB
22	MLT-0.5, 1.5 kΩ IA	38	SP-1-0S 520 A, 1 W, 2.2 kΩ
23	MLT-0.5, 7.5 kΩ IA	39	MLT-0.5, 1.5 kΩ IIA
24	MLT-0.5, 5.6 kΩ IIB		

Capacitor Data

1-2	MB-0.01-III	17	EM-6-15N, No. 2
3-6	MBM-I-II	18-20	EM-10-15N, No. 2
7-9	EM-30-IN	21-22	EM-4-25N, No. 3
10	EM-10-IN	23-25	BM-0.03-III
11-13	MBM-I-II, No. 2	26-28	BM-0.025-III
14	MBM-0.5-II	29	KBG-4-200-0.1-III
15	EM-10-3N	30	MBM-0.05-III
16	EM-6-5N	31	KE-2-20/100

The general design of the instrument is similar to that of the EKPS-2 electrocardiograph which was described earlier, with the exception of the control panel and the presence of two galvanometers with a common light, as well as panels containing parts of the audio channel amplifier. The apparatus is mounted in the same cabinet, so that it has overall dimensions of 240 × 400 × 290 mm and weighs 16.5 kg.

The control panel of the instrument is shown in Figure 62. On the left-hand side (as in the EKPS-2) there are the following: the feed container 30, near it window 9 for observing two spots of light, and button 26 for adjustment. Above them we can see the indicator 20 for paper supply, button 19 for starting the film-transport mechanism, power switch 2 and damper switch 18 (EKG channel). Further toward the top of the panel are located the socket 31 for connecting an oscillograph to the EKG channel, a connection 17 for the vector electrocardioscope VEKS-0.1, the phonocardiogram can be observed on its screen, socket 16 for connecting the microfilm, socket 32 for connecting the oscillograph leads to the photochannel, a connection for the cable containing the leads from the electrodes, and handle 25 for lifting the apparatus out of the cabinet. /70

In the following order from left to right we have: knob 5 for the potentiometer for constant regulation of sensitivity (amplification) in the EKG channel, knob 6 for similar regulation of the audio channel, knob 24 for the switch controlling the frequency characteristics of the audio channel, and knob 4 for the lead switch.

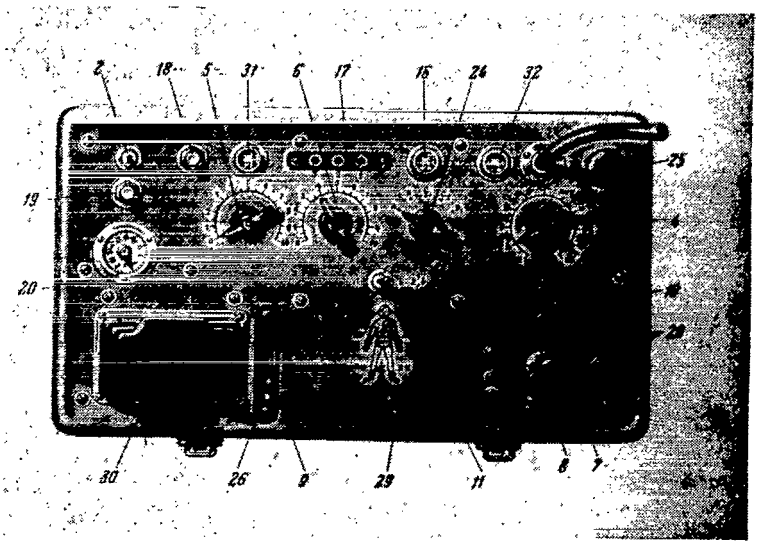


Fig. 62. Control Panel of FEKP-2 Phonoelectrocardiograph.

Below these are toggle switch 11 for course regulation of sensitivity of the audio channel (1 to 2.5) and button 10 for the calibration signal to the EKG channel. At the bottom right are toggle switch 29 for course regulation of sensitivity of the EKG channel (1 to 2), knob 7 for vibrator adjustment (setting the zero line) in the EKG channel, knob 8 for adjusting the audio channel vibrator, and heads 28 of the screws for adjusting the angles of the vibrators.

The equipment supplied with the apparatus is the same as with the EKPS-2 (see above). In addition, the following equipment is provided: a microphone with cover, a rubber strap with three snaps, a control block, a connecting cable 3 m long, and a connecting lead with clamp.

To record a phonocardiogram, the microphone is strapped to the patient's chest with a T-shaped rubber strap. It is necessary to ensure that the rubber ring lies as flat as possible against the surface of the body without making it difficult for the patient to breath. The three-pronged plug of the microphone is then inserted in the socket on the control panel and the nut is tightened.

In recording electrocardiograms, all the precautions mentioned /71
previously in connection with recordings made on the EKPS-2 should be followed, as well as some special instructions regarding its use.

It is also possible to connect two separate oscilloscopes for observing the EKG and PKG. By using a connecting cable (included in the equipment), the oscilloscopes are connected to the proper sockets 31 and 32 on the control panel.

A loudspeaker, tape recorder, or vector electrocardioscope for listening to the recordings or observing the phonocardiograms can be connected to the terminal strip 17. The voltage between the prongs of the terminal strip 1, 2, and 3 (see Fig. 61) is about 1 mV at sound pressures in the receiving chamber of the microphone on the order of 1 bar. The output resistance between the prongs is 500 Ω.

The vector electrocardioscope (VEKS-01) is connected to terminals 1 and 2 by means of any two wires in the lead cable. The lead switch is then set to the proper position. The grounding clamp of the VEKS must be connected to the lead which connects the apparatus to grounding socket 3 on the phonoelectrocardiograph.

The microphone or loudspeaker is connected to the phonoelectrocardiograph by means of the connecting cable provided with it. The wires in this cable are connected to terminals 1 and 2 on the terminals strip and to the microphone inputs of the tape recorder or loudspeaker. The wires in the cable marked "ground" must then be connected to socket 3 for grounding to the chassis and to the proper terminal on the loudspeaker or tape recorder.

The phonoelectrocardiographic channel is very sensitive to external disturbances both from alternating magnetic fields and from various mechanical and acoustical vibrations. To get rid of interference of the first type (e.g., from power transformers, regulating autotransformers of type LATR, other electrocardiographs and instruments operating in the vicinity), the sources of this noise should be removed or else the instrument itself should be shifted as far away from them as possible. To prevent acoustic noise, sound absorbing materials can be used in a number of instances to cover the walls or in the form of carpets, drapes, etc.

All of the remarks made earlier with respect to the use of the EKPS-2 are valid in this case as well.

§ 3. ELECTROCARDIOGRAPH, SINGLE-CHANNEL, WITH INK RECORDING

A portable, single-channel electrocardiograph, for operation on line voltage, equipped for ink recording on a paper strip was developed by VNIIMIO and is being produced by the "Red Guard" Factory (Model 060 or No. EKSPCh-4). The data on this instrument generally correspond to those on the EKPS-2 instrument which operates on line voltage with photoelectric recording. The following are some additions and changes:

1. Recording is made on a strip of paper 30 ± 0.5 mm wide. There are about 50 m of paper on a spool.

2. The rate of travel of the paper is 50 mm/sec.

3. Maximum sensitivity is 20 mm/mV.

4. The frequency characteristic is uniform within limits from 0.3 to 80 Hz, with a drop-off of no more than 10% in the terminal frequencies.

5. The thickness of the recording line at zero is no more than 1.5 mm, while the front of the calibrating signal is 0.5 mm.

6. The power drawn from the line is 120 V-A.

7. The overall dimensions are 130 × 205 × 390 mm, and the weight is 10.5 kg.

The principal difference between this instrument and the electrocardiograph using photoelectric recording is the equipment in the recording section. The latter is fitted with a film-transport mechanism, activated by a synchronous electric motor. A motor of /72
this type ensures a constant rate of travel for the paper, so that time markings are not provided for in the instrument. The recordings are made with an electromagnetic vibrator fitted with a pen. The tip of the pen oscillates along the arc of a circle whose radius is equal to the length of the pen. Therefore, the shape of the

recording is different from that produced by the photoelectric method, where the beam of light moves across the paper perpendicular to its midline. To facilitate reading the recordings on the paper, a curved scale grid is printed on it.

The schematic diagram of the amplifier is shown in Figure 63. The amplifier operates in a push-pull (differential) regime, and consists of four stages. The first three use 6N2P tubes (V_1, V_2 and V_3) to amplify the voltage, while the final stage uses 6P14P tubes (V_4 and V_5) as power amplifiers.

The cable carrying the wires from the electrodes is connected to the apparatus via the lead switch (marked S_1 in the diagram). This cable is fitted with a six-pronged connector C_1 (there is a plug on the end of the cable and a matching socket on the side of the cabinet). The line switch is in turn connected to the amplifier section by a three-pronged connector C_2.

Since the amplifier as a whole is similar in design to the amplifier described above for the EKPS-2 (see Fig. 52), we shall deal with only a few of its features. The negative feedback on the grids of the first, second and third stages is accomplished by resistors 6, 20 and 25. A positive bias on the grids, on the order of 30 V, is produced by connecting the common zero lead of the amplifier to the center tap of the voltage divider via resistors 52 and 53. To keep the feedback from the alternate component out of the circuit, resistor 53 is shunted by capacitor 8.

Therefore, the potential of the chassis (to which the zero lead of the circuit is grounded) is about 30 V higher than the potential of the common minus of the power source, to which the cathodes of the tubes are connected. This makes it necessary to ground the apparatus during operation.

To balance the arms of the amplifier, the circuit of tube V_2 in the second stage includes variable resistors 16 and 17, which are connected in such a way that when the signal on one of the grids increases, the signal on the second grid decreases and vice versa. The resistors are located beneath the slit and can be adjusted if necessary. Also located beneath the slit is the adjustable resistor 30, which shunts the anode circuits of the tubes in the second stage. This resistance can be used to set the value of maximum sensitivity (amplification) for the entire amplifier.

Smooth regulation of sensitivity (amplification) is accomplished by double potentiometers 23-24, with a linear characteristic; the potentiometer is connected in the grid circuits of the third stage and is mounted on the control panel. Step-wise variation of sensitivity (1 to 2) is accomplished with switch S_2 by switching resistors 74 and 75 and 26 and 27.

In the circuit of the output stage, the negative feedback is

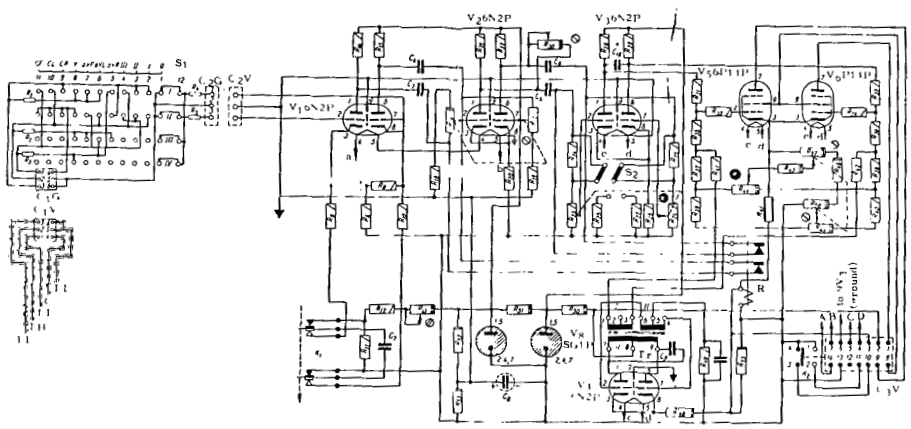


Fig. 63. Schematic Diagram of Amplifier of EKPSCh-4 Electrocardiograph.

produced by resistor 47, connected to the common circuit of the tube cathodes. In parallel with it are resistors 46, 57 and 58. The latter two are coupled, mounted beneath the slit, and intended for adjusting the sensitivity of the amplifier when setting it up. The grid circuits of tubes V_5 and V_6 contain variable resistors 44 and 45 for balancing the arms of the section. Resistor 44 is mounted on the control panel and serves to regulate the position of the zero line in the recording. Resistor 45 is mounted below the slit and is used to set the middle position of the zero line when the tubes in that stage are replaced.

In series with resistor 47 in the cathode circuits of tubes /73
V_5 and V_6 is winding R of the damper relay, whose contacts close the circuits to the coupling capacitors 3 and 4 and 5 and 6 beyond the first and second stages. The amplification then drops practically to zero. When the amplifier is operating and the film-transport mechanism is switched on, current passes through the winding and the contacts of the damper close. If the film-transport mechanism (or in this case the paper-transport mechanism) is shut off (see below), e.g., when changing the recording or changing the setting of the lead switch, microswitch K_3 is the right-hand position (see Fig. 64) and connects sockets 3 and 10 on the terminal strip MR_3. This means (see Fig. 63) that winding R of the relay (is shorted through contacts 3 and 4 of button K_2), so that the contacts of the damper close.

If it is necessary to perform damping when turning on the paper-transport mechanism (microswitch K_3 in the lefthand position, terminals 3 and 11 of the connecting strip C_3 connecting), it is necessary to press the damper button K_2 on the control panel. This button closes the circuit to terminal 11, and winding R of the relay again is shorted out; the contacts of the damper close. Finally, if it is necessary to check the operation of the pen (amplitude of recording, position of the zero line, etc.) when the paper-transport mechanism is shut off, the damper button K_2 must be pressed several times on the control panel. The circuit which shorts the winding of the relay is then interrupted, so that the contacts of the damper are also opened.

A 1 mV calibrating signal is formed in the cathode circuit by the first tube when button K_1 is pressed. It is produced by the discharge of capacitor 7, with a capacitance of 160 μf across the voltage divider consisting of resistors 9, 7, 8, and 10. When the button is released, capacitor 7 is charged by the voltage (10 V) produced across resistor 11, connected in series with resistors 12 and 13 to the stabilized supply voltage (105 V). Resistor 13 is mounted below the slit. It is set at the factory. Depending on the charge in capacitor 7, the signal voltage drops slowly (the time constant of the circuit is 40 sec). Hence, the height of the calibrating signal must be estimated from the leading front.

To get rid of hysteresis in the magnetic circuit of the vi-

brator and to reduce the friction of the pen against the paper (see p. 88), which can have a significant influence on the shape of the recording, an additional alternating voltage with a frequency of 300-350 Hz is fed to the control grids of the tubes in the input stage. This is accomplished with a generator operating with a 6N2P tube (V_4), using a push-pull circuit with inductive coupling between the anode and grid circuits; the latter is formed by transformer Tr_1.

The anode circuits of tubes V_5 and V_6 in the output stage are connected differentially to the coils of vibrator 4 PG through contacts 1 and 9 of C_3 (see Fig. 63) as well as contacts 1 and 3 of C_4 (see Fig. 64); a portion of the wires are shunted (to improve their frequency characteristic) by capacitor 17. The plus side of the supply voltage runs to the center tap of the coil through terminal 2 on C_4.

Capacitor Data

3-6 KBG-MN, 200-I-I
7 MBGP-3, 160 A-4-II
8 EGTs-2B, 150/50 M
9 KSO-5, 500 B-3000-I
10 KBG-I, 200, 0.02-II
11 KBG-I, 600-0.01-11
12 EGTs-2B, 30/1000 M
13 KE-2, 300-30 M
14-15 KE-2, 450-20 M
16 MBGCh-1, 250-7-I-II
17 MBGP-3, 200-A-I-II
18 KSO-5, 500-B-4700-10 000-II

Resistor Data /74

1-3 MLT-0.5, 30 kΩ I-A
4-5 MLT-0.5, 4.7 kΩ I-A
6 MLT-0.5, 360 kΩ I-A
7-8 MLT-0.5, 510 Ω I-A
9-10 MLT-0.5, 51 MΩ I-A
11 MLT-0.5, 10 kΩ I-A
12 MLT-0.5, 82 kΩ I-A
13 SP-I-OS 312 gr IV-A 2 W 47 kΩ
14-15 MLT-0.5, 220 Ω IA
16-17 SP-III-OS 312 A 0.5 W 1 MΩ / A 1.0 W 1 MΩ
18-19 MLT-0.5, 2.4 MΩ I-A
20 MLT-0.5, 360 kΩ I-A
21-22 MLT-0.5, 220 kΩ I-A
23-24 SP-III-OS 520 A 0.5 W 3.3 MΩ / A 1.0 W 3.3 MΩ
25 MLT-0.5, 3.9 kΩ I-A
26-27 MLT-0.5, 3.3 MΩ I-A
28-29 MLT-0.5, 220 kΩ I-A
30 SP-I-OS 312 IV A 2 W, 1 MΩ
31-32 MLT-0.5, 1.0 MΩ I-A
33-34 MLT-0.5, 2.2 kΩ I-A
35-36 MLT-0.5, 1.5 MΩ I-A
37-38 MLT-0.5, 56 kΩ IA
39-40 MLT-0.5, 10 kΩ I-A
41-42 MLT-0.5, 270-330-390 kΩ I-A
43 MLT-I, 360 kΩ I-A
44 Sp-I-OS-520 IV A, 2 W 47 kΩ
45 SP-I-OS-312 IV A, 2 W 47 kΩ
46 MLT-I-10 kΩ I-A
47 PE-7.5, 1 kΩ I
48 MLT-1, 3.9 kΩ I-A
49 MLT-0.5, 1 kΩ 10-A
50 MLT-2, 3 kΩ I-A
51 MLT-2, 5.1 kΩ I-A
52 MLT-1, 91 kΩ I-A
53 MLT-1, 36 kΩ I-A
54 PE-7.5, 3.5 kΩ I
55 PE-7.5, 3.5 kΩ I
56 MLT-2, 150 Ω I-A
57-58 SP-III-OS-312 A 0.5 W 4.7 kΩ / A 1.0 W 4.7 kΩ
59-70 MLT-0.5, 22 kΩ I-A
71 MLT-0.5, 5.6 kΩ I-A
72 MLT-0.5, 100 Ω I-A
73 MLT-1.0, 510 Ω I-A
74-75 MLT-0.5, 1.5 MΩ II-A

The power supply, whose schematic is shown in Figure 64, is also essentially analogous to the power supply in the EKPS-2, con-

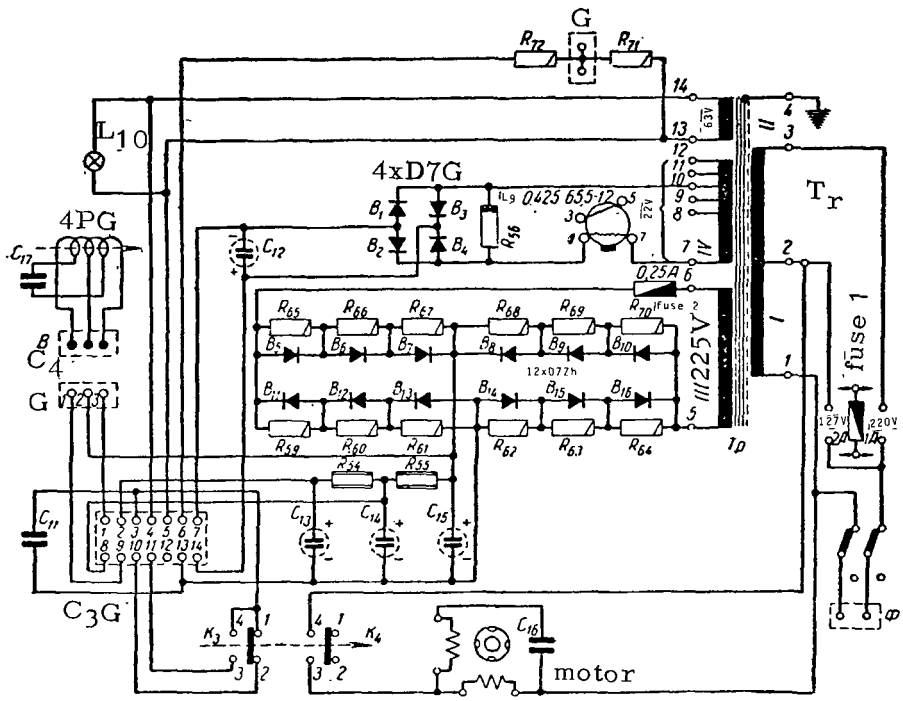


Fig. 64. Schematic Diagram of Power Supply for Amplifier of EKPSCh-4 Electrocardiograph.

sisting of a power transformer Tr and two rectifiers: one consisting of 12 D7Zh diodes for powering the anode surface in the amplifier and the low-voltage rectifier consisting of four D7G diodes for powering the tubes in the first and second stages. The heating current for the tubes is stabilized by a ballast tube (V_9). The voltage in the ballast tube circuit is adjusted by means of terminals 8 and 12 of the transformer winding. The heating of the rest of the tubes is accomplished by means of a separate winding V on the transformer. This same winding also supplies pilot light L_{10} when the apparatus is plugged into the line and the voltage divider (resistors 71 and 72) which supplies a voltage of 0.11 V between the terminals G and the chassis of the apparatus; this voltage is used for balancing the amplifier. /75

Electric motor M of the paper-transport mechanism is connected to the primary winding of the transformer (127 V terminals) through the contacts of microswitch K_4.

The supply voltage for the anode circuits is filtered by a

two-stage filter consisting of resistors 54 and 55 and capacitors 13-15. Using capacitor 15, voltage at 230-240 V is fed to the anodes of the tubes in the output stage (through the center tap and coils of the vibrator), while a voltage of 220 V passes through capacitor 14 to the screen grids of the tubes in the output stage (through socket 8 on C_3. A voltage of approximately 200 V passes through capacitor 13 to socket 2 on C_3 and then to the anodes of the frequency generator (300 Hz), and to the block consisting of two stabilitrons SG1P (V_8) and SG2P (V_7) (see Fig. 63). From stabilizer V_8, the voltage passes to the anode of the tube in the third stage. From stabilizer V_7, the doubly stabilized voltage passes to the anodes of the tubes in the first and second stages and to the voltage dividers for the calibrating signal (resistors 11-18) and the positive bias on the grids (resistors 52 and 53).

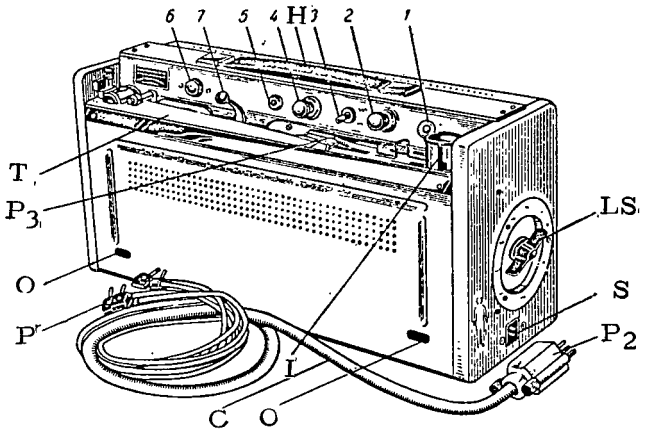


Fig. 65. Overall View of EKPSCh-4 Electrocardiograph.

A general view of the apparatus with the cover removed is shown in Figure 65. All of the parts of the instrument are mounted on a chassis within a metal cabinet with removable front and back covers. A removable lid covers the recording portion of the apparatus and can be removed for repairs. On the top of the cabinet, mounted on a hinged cover, is handle H for carrying the apparatus. Figure 65 also shows cable C with wires from the electrodes and plug P for plugging the apparatus into the wall. On the right-hand side of the cabinet is socket S for plugging in the plug at P_2 of the cable with the leads from the electrodes, and above the knob LS of the lead switch.

At the top center of the cabinet is a horizontal plate (table) T, along which the paper moves when recording is taking place; at the right are the pen P_3 of the vibrator and the ink holder I. Behind the recording plate is a vertical control panel, on which are mounted the following, from right to left: button 1 for the calibrating signal, knob 2 for regulating the sensitivity (amplification), toggle switch 3 for step-wise regulation of the sensitivity, knob 4 for setting the zero line of the recording, button 5 for the damper and lens 6 of the pilot light. Somewhat forward of the panel is knob 7 for controlling the paper-transport mechanism. /76

Figure 66 is a schematic representation of an exterior view of the apparatus with the front cover removed. To remove this

cover, it is necessary to press down the retaining springs holding it in place S_3 (Fig. 66) through openings O (Fig. 65).

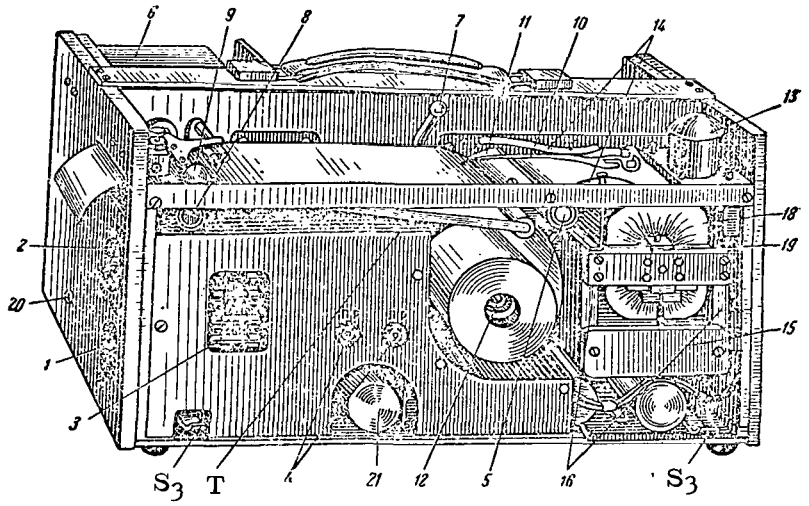


Fig. 66. View of EKPSCh-4 Electrocardiograph With Front Cover of Cabinet Removed.

The following are located on the left-hand side of the cabinet (Fig. 66): socket 1 for the line switch plug, line switch 2 and socket 20 for the grounding wire. On the front of the cabinet are the fuses 3, including the line fuse which serves for switching over from 127 to 220 V, as well as socket 4 for the voltage divider for balancing the amplifier with a cophasal signal (see Fig. 64); below the socket is tube 21, a horizontally mounted ballast tube. To the right is the electromagnetic vibrators 16. Between the latter and the paper roll is knob 5 for regulating the resistance (No. 13 in the diagram on p. 81) in the calibrating signal circuit.

The paper-transport mechanism consists of an electric motor 6 mounted at the left in the back of the cabinet (see Fig. 68), a gear reduction mechanism, a capstan 8 and a pressure roller 9.

The recording section operates as follows (Fig. 65 and 66). Knob 7 which controls the paper transport mechanism has three fixed positions, marked by the letters R, C and F, and is used both to turn on the electric motor (through microswitch K_3K_4, see Fig. 64), which drives the paper, as well as the position of the table T, along which the paper moves. In the left-hand position R (run) the electric motor is switched on and the table is in a horizontal position; pen 10 of the vibrator is in contact with the paper, which is compressed by the pressure roller and taken up on the spool 8. At the other end, the paper is pressed against the table by a spring /77 11. The supply roll of paper is mounted freely on axle 12.

With the control in the middle position C (check), the electric motor is switched off, the right-hand part of the table is lowered, the pen is not in contact with the paper, and pressure roller 9 is raised. In this position (with the paper already having been inserted) the pens can be cleaned and checked. Ink holder 13 is located at the right. In the right-hand position F (fill) the movable part of the table is depressed still further, thus making it possible to have ready access to the paper supply. The paper is led along the table, and the free end is passed between the pressure roller and the capstan, emerging from a slit in the left-hand side of the cabinet so that about 5-10 cm protrude; knob 7 is then set to position R.

On both sides of pen 10 are stops 14, which raise the pen and keep it from touching the paper when its excursions are greater than the normal width of the recording.

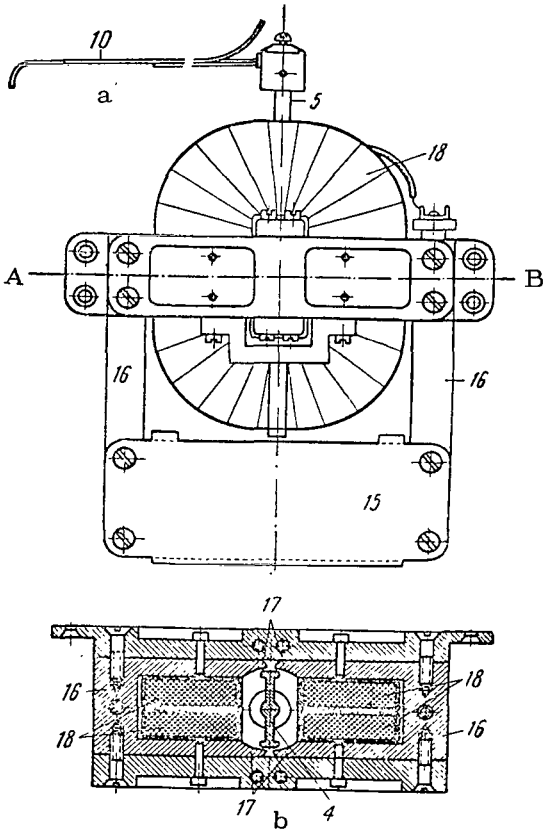


Fig. 67. Overall View (a) and Cross Section (b) of the Vibrator Used in the EKPS-4 Electrocardiograph.

A general view of the vibrator is shown in Figure 67, a (see also Fig. 66), while the horizontal cross section (along the line AB) is shown in Figure 67, b. The vibrator is an electromagnet, which is polarized and consists of a powerful permanent magnet 15, a bilateral magnetic winding 16, pole pieces 17, with coils 18 and head 19 mounted between them; flat springs are used to hold armature 4 inside head 19. A vertical rod 5 comes from the armature through an opening in the panel at the level of the writing table T, and carries on its upper end a support for mounting the pen 10. The principle of operation of this vibrator is the same as in the EKPS-2: the alternating magnetic field of the coils, reacting in the magnetic windings with the field of the permanent magnet, amplifies the latter at one pair of pole pieces (located diagonally) and weakens it in the other. As a result, a rotational moment acts on the armature, which changes its sign and causes the armature to oscillate in accordance with the current

passing through the coils. These oscillations are recorded by the pen on the paper.

The pen consists of a thin steel tube with an internal diameter of 0.3 mm, 100 mm long, mounted on a thin metal strip for rigidity. The ink is fed by capillary action through a plastic tube /78 which connects the pen and the ink holder. When beginning recording, the pen must be filled with ink; this is done by covering the opening in the lid of the ink holder with the finger and pressing down.

To reduce the friction of the pen against the paper and improve the conditions for remagnetizing the armature and returning it to the middle position in the vibrator coils, an additional alternating voltage at a frequency of 300-350 Hz is applied; this voltage causes a steady "buzzing" of the armature at an amplitude which is nearly invisible to the eye.

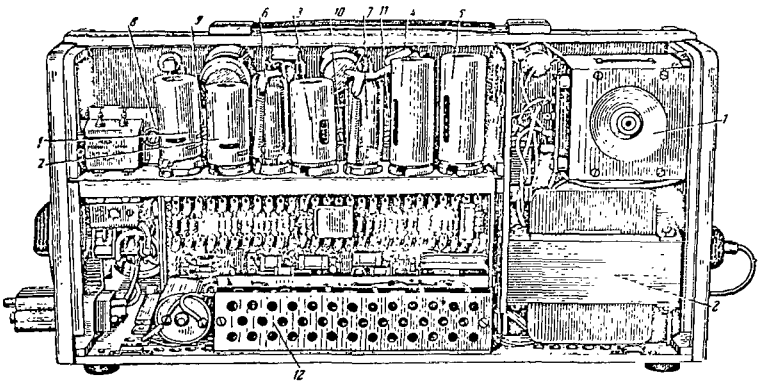


Fig. 68. View of EKPSCh-4 Electrocardiograph With Rear Cover Removed.

Figure 68 shows a view of the apparatus with the rear cover removed. At the right are electric motor 1 and power transformer 2. At the left are the amplifier components. On the upper level are the tubes: 1 and 2 are the tubes in the first and second stages, 6 is the stabilitron for powering them, 3 is a tube in the third stage, 7 is a stabilitron for powering it, 4 and 5 are the tubes in the output stage, while behind them is the tube for generating 300 Hz frequency to power the vibrator. Beside the shield for tube 1 are knobs 8 and 9 for controlling resistor 16-17 and 30 (see Fig. 63). Beside the shield of tube 7 are knobs 10 and 11 for resistors 57-58 and 45 (see Fig. 63). The lower section contains resistors and other amplifier components, as well as the semiconductor diodes of the power supply, located behind partition 12.

List of parts:

1. Instrument as supplied with tubes and fuses.

2. Power cord (2 m); grounding wire (8 m) with clamp.
3. Cable with electrode leads.
4. Electrodes for extremities (4) and chest (1).
5. Wrenches for removing pen (1) and mounting head (1).
6. Eye dropper, screw driver, box for parts, cover.
7. Spare parts:
(1) Roll of graph paper.
(2) Pens (10), cleaning wires (0.2 mm; 200 mm long) (10), plastic tubing (100 mm long) 10.
(3) Electrode for extremities (1), rubber strap (1).
(4) Fuses: PK-30, 0.25 A (3); 1.0 A (5); 2 A (5).
(5) Vacuum tube (for first stage) 6N2P (1).
(6) Heating lamps MN-16 (13.5 V, 0.18 A) (2).
8. Description and operating instructions.

The following are some brief instructions for using the apparatus to make recordings. Check the zero position of the knob on the control panel and set the line switch to the off position. /79
Check to be sure that there is an adequate supply of paper. Fill the ink holder with ink and fill the pen with ink. Connect the ground wire (carefully!). Check the setting of the fuses. Connect the line cord to the wall socket. Connect the cable with electrode leads to the apparatus. Turn on the apparatus by throwing toggle switch 2 (Fig. 65), so that pilot light 6 lights up. After waiting for two minutes for the apparatus to warm up, set knob 4 so that the pen is in the middle of the paper. Ten minutes after turning on the apparatus, set the paper-transport mechanism in motion and use knob 2 to set the sensitivity at 10 mm/mV (simultaneously pressing and releasing button 1 of the calibrator) to ensure that the pen excursion is 10 mm (not counting vibration). Set knob 7 to position C. The apparatus is ready to operate.

Recall that if the recording is being made in a metal bed, both the apparatus and the bed must be grounded.

To make a recording, the lead switch must be set to the proper position, button 5 of the damper must be pressed, the pen must be inspected to see if it is working properly, and only then can knob 2 be used to set the sensitivity so that the maximum excursion of the pen does not go beyond the lines on the paper. Release button 5. Use knob 7 to start the paper-transport mechanism and record a calibrating signal on the electrocardiogram. Turn off the paper-transport mechanism.

After the recording has been made, remove the ink from the ink holder and blow air through the pen so that when a finger is placed over the opening, the lid of the ink holder goes up and down several times.

When first connecting the apparatus to the line, after receiving it, it must be allowed to dry out for 24 hrs with the sides of the cabinet removed, at a temperature of 15-20°. The factory ships the apparatus ready for use on a 220 V line.

§ 4. TWO-CHANNEL ELECTROCARDIOGRAPH WITH INK RECORDING

A two-channel electrocardiograph for use with line voltage and ink recording on paper was developed by VNIIMIO and is being produced by the "Red Guard" Factory, under the designation of Model 047 or EKPSCh-3. Two separate channels make it possible to simultaneously record electrocardiograms from two leads. In addition, by connecting suitable attachments, the pulse can be recorded from the electrocardiogram on one channel while respiration and other processes are recorded on the other channel.

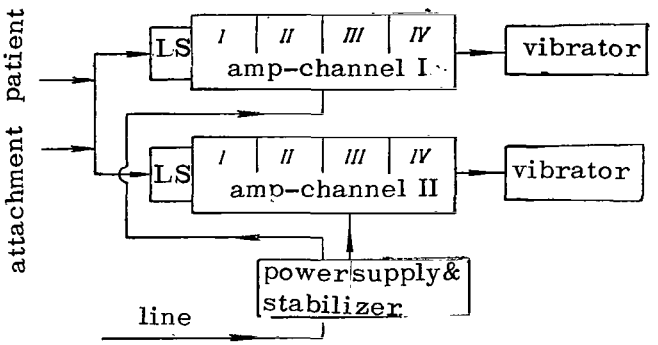


Fig. 69. Block Diagram of EKSPCh-3 Electrocardiograph.

The principal data on the apparatus are similar (for both channels) to that given previously for the EKPSCh-4. The following are additional details:

1. The recordings are made on a roll of paper 70 mm wide (approximately 50 m per roll). The effective recording width for each channel is 25 mm.

2. The paper travels at speeds of 25, 50 and 100 mm/sec.

3. Maximum sensitivity is 20 mm/mV.

4. The frequency characteristics are as follows: (a) broad band, uniform within the limits of 0.2 to 100 Hz, and (b) narrow band, uniform from 0.2 to 30 Hz, with a drop-off of no more than 20% at the limiting frequencies. /80

5. Power consumption is 200 V-A.

6. Operating regime: a rest of at least 30 min is required after four hours of constant operation.

7. The overall dimensions are 210 × 285 × 500 mm. The weight of the apparatus is 25 kg.

The input section of the apparatus consists of a lead switch for each channel and a common cable with leads from the electrodes. The cable contains six wires: four from the electrodes for the extremities and two from the chest electrode: the latter are marked with black for channel I and blue for channel II.

A block diagram of the electrocardiograph is shown in Figure 69. The electrical section of the apparatus consists of three principal sections, linked by removable connectors ("plug-in leads"): the amplifier block, the power supply block, and the stabilizer block. The schematic diagram of the amplifier block is shown in Figure 70.

The amplifier has two input sockets: for channel I, marked "patient" SP_{01}, into which is plugged the cable with the leads from the electrodes, and the socket for the second channel, marked "attachment", SA_{02}, into which is plugged the short-circuiting plug SC_{02} when electrocardiograms are being recorded on both channels. Each channel can be connected to any of 10 leads.

When attachments are used, the short-circuiting plug is removed and replaced by a cable from the attachment (the output resistance of the attachment must not exceed 1000 Ω). The lead switch of the corresponding channel is set to the zero position.

The amplifiers for both channels are the same, each consisting of four stages with resistance-capacitance coupling: three stages using 6N2P tubes for amplifying voltage, and the fourth containing 6PIP tubes for amplifying power and operating in a push-pull, differential circuit with strong negative feedback, which reduces amplification by cophasal signal and is similar in general respects to the amplifier of the EKPSCh-4 instrument (Fig. 63). Therefore, we shall describe it only in general.

The input to the grids of the first stage contains high-frequency filters to combat noise; these consist of leakage resistors 010-011 or 012-013 and capacitors 04 and 03. (In the following, the data which refer to the second channel will be enclosed in parentheses.) The cathodes of the first, second and third stages are connected to high-ohmage resistances for feedback, 021, 029, 036 (083, 075, 070). The grid circuit of the second stage contains a double potentiometer 086-087 (088-089), which can be used to balance the arms of the amplifier.

A toggle switch S_{03} (S_{04}) can be used to shunt the cathode circuits of the second stage tube with resistor 0113 (0114) and thereby change the sensitivity (amplification) of the amplifier step-wise in a ratio of 1 to 2.

The grid circuit of the third stage contains a double potentiometer 034-035 (068-069), which can be used to regulate the sensitivity of the apparatus during assembly. The anode circuits of the tubes in the third stage are linked by capacitor 013 (014), in series with which is resistor 037 (067). When the latter resistance is short-circuited by switch S_{05} (S_{06}), the band of the frequency characteristic of the amplifier becomes narrower.

The output stage contains milliammeter M_1 (M_2) in the cathode

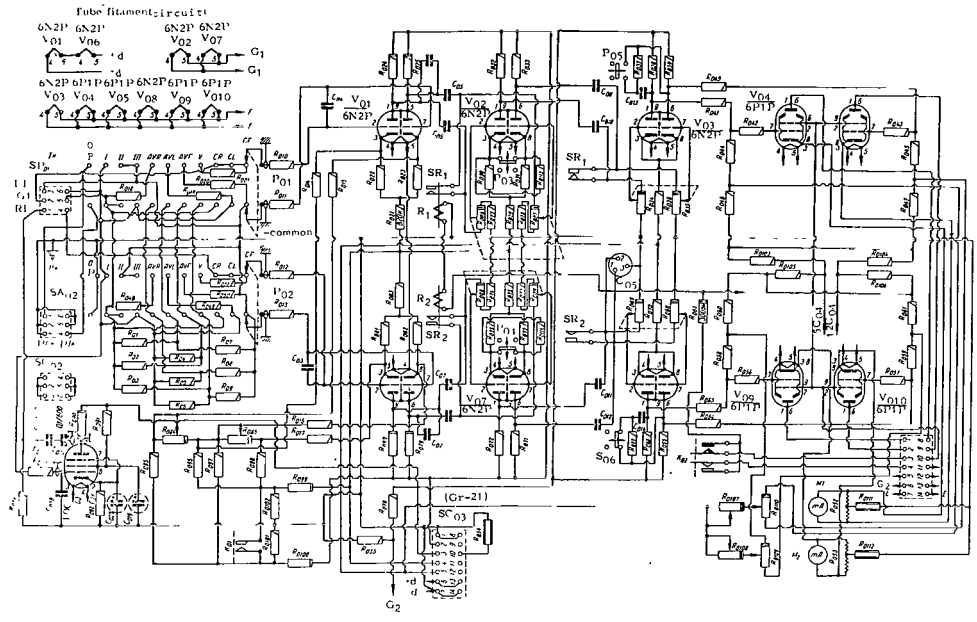


Fig. 70. Schematic Diagram of EKPSCh-3 Electrocardiograph.

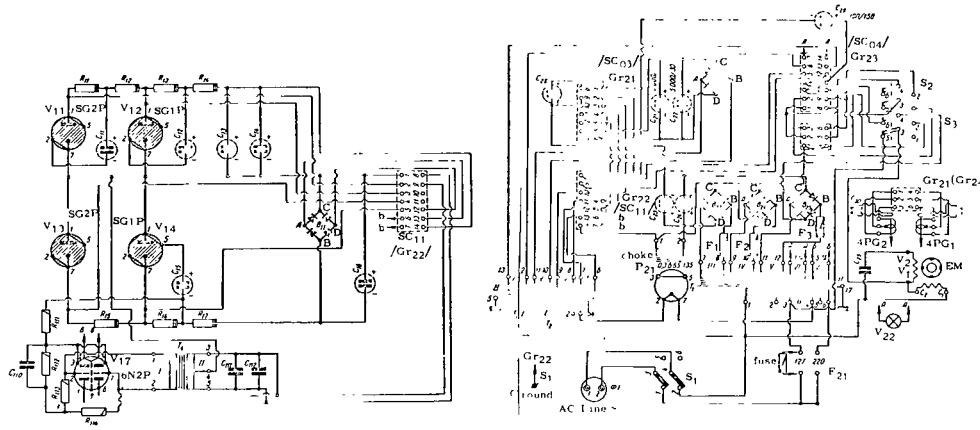


Fig. 71. Schematic Diagram of Power Supply of EKPSCh-3 Electrocardiograph.

circuit of the tubes, connected by shunts 052 (053), making it possible to set the zero line and adjust the amplifier without turning on the recording mechanism.

The grid circuits of the output stage contain variable resistors /81
0110 (0109), which balance the arms of the amplifier and serve to set the zero line of the recording. The center tap of this resistance provides an independent control through a regulated resistance 0107 (0108) which can be used to regulate the sensitivity of the amplifier for each recording.

The anode circuits of the tubes in the output stage pass through the contacts of the screw connectors SC_{04} (Gr_{23}) and then SC_{21} (Gr_{24}) which are connected to the coils of the vibrators VC_1 and VC_2 (see Fig. 71). The vibrators have the same construction as in the EKPSCh-4 instrument, but additional windings are provided (shunted by capacitor 30 (or 31), for improving the frequency characteristic.

To avoid excessive currents in the tubes when switching leads, an automatic mechanism is designed for setting the positions of the electrodes, etc., in the amplifier: when the paper-transport mechanism is turned off by a double switch S_2-S_3 (see diagram in Fig. 71), relays R_1 and R_2 are switched on whose contacts (KR_1 and KR_2) short-circuit the grids of the triodes in the tubes of the second and third stages in both channels. The relays receive independent power from the output of the rectifier R_{25} (see below). The contacts of S_2 then short-circuit the anodes of the tubes of the output circuits. To check the operation of the amplifier when the paper-transport mechanism is shut off, button K_{02} can be pressed to shut off the relay. The anodes of the tubes in the output stages then remain short-circuited (by the contacts S_2) and the armatures of the vibrators do not move. The operating regime of the amplifier can be monitored by watching the pointers of the milliammeters.

When the paper-transport mechanism is switched on, relays R_1 and R_2 are disconnected, the anodes of the output tubes are not shunted, and the amplifier operates normally. Under these conditions, when button K_{02} is pressed, only relays R_1 and R_2 are connected, short-circuiting the grids of the tubes in the first and second stages, so that the amplification falls to zero.

A calibrating signal of 1 mV is supplied by pressing button K_{01} simultaneously in the cathode circuits of both channels. The signal is produced in resistors 014-015 and 016-017 from a complex multi-stage voltage divider contain resistors 095-084-096 (097-085-098), connected to the doubly stabilized source of bias voltage.

A compensating mechanism is provided in the apparatus to compensate for noise at the 50 Hz frequency, formed at the electrodes due to the capacitance between the body of the patient and the wires around him. The compensator is an amplifier using a 6ZhIP tube,

V_{011}, whose input is a shielded wire connected to the "LH" electrode, and whose output is also a shielded wire which passes through the blocking capactors 021-022 with insulation intended for a high operating voltage, connected to the "RH" electrode. The compensation ensures that a voltage opposite in phase to the noise voltage appears across the electrodes applied to the patient, thus compensating for it.

In addition, the apparatus is also provided with an alternating current generator for a frequency of 300 Hz, the voltage from which is used to improve the remagnetization of the vibrator armatures and reduce the friction of the pens against the paper. The generator operates with a 6N2P tube (V_{17}) (Fig. 71). Its voltage passes to the grids of the tubes in the output stage through contacts 8 and 9 on SC_{11} and contacts 6-12 on SC_{04} (Fig. 70).

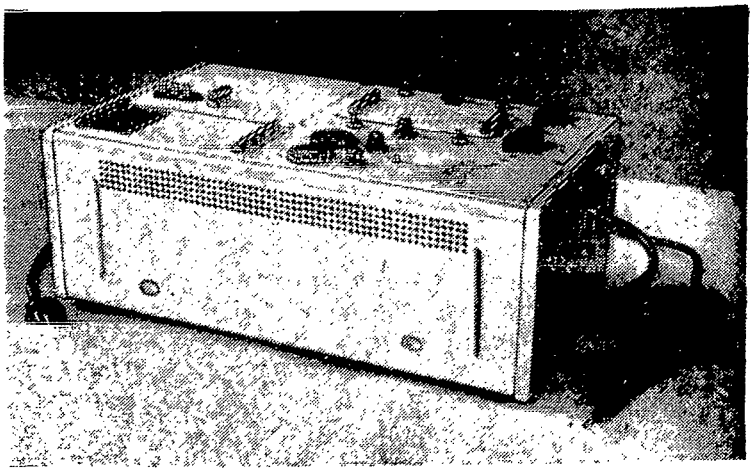


Fig. 72. Overall View of EKPSCh-3 Electrocardiograph.

The power of the amplifier comes from the power supply and the stabilizer section connected to it (Fig. 71). The power supply contains a power transformer T_1 and auxiliary transformer T_2, whose primary winding supplies the current which is stabilized by ballast tube V_{21} (0.3 B-65-135). The electric motor EM of the paper-transport mechanism is connected to the primary winding of transformer T_1. Three secondary windings (III, IV, V) feed three bridge rectifiers B_{23}, B_{24}, B_{25}, each of which consists of four D7G diodes. The rectifiers are connected in series and provided with a filter consisting of choke L and capacitors 23-24. They supply a rectified voltage of 280-300 V. The voltage from the first rectifier B_{25} passes through contacts 4 and 6 on S_3 and contact 4 on SC_{04} to the contacts of switch K_{02} (Fig. 70), continuing on to the windings of the damping relay. /82

The voltage from contact 1 on L passes through contact 1 and 4 on SC_{21} to the center tap of the vibrator coils. In addition, it passes through contacts 10 on SC_{04} to the screen grids of the tubes in the output stages (Fig. 70). It passes through contact 14 on SC_{11} (Fig. 71) to capacitors 13 and 14 of the ripple filter and to stabilitrons V_{12} (SG1P) and V_{11} (SG2P). The voltage runs from the first stabilitron V_{12} through contacts 3 on SC_{11} and SC_{03}

(Fig. 70) to the anodes of tubes V_{03} and V_{08} of the third stages of the amplifier, as well as to the anodes V_{11} of the noise compensator, operating at 50 Hz. The voltage runs from the second stabilitron V_{12} through contacts 2 on SC_{11} and SC_{03} (Fig. 70) to the anodes of tubes V_{01}, V_{06}, and V_{02}, V_{07} in the first and second stages of the amplifier.

A voltage of 6.3 V runs from winding VI of the transformer T_1 (Fig. 71) through contacts 7 and 14 of SC_{04} (Fig. 70) to the heaters of the tubes in the third and output stages and is also used for powering the pilot lamp L_{22} (Fig. 71). Winding VII of the transformer T_1 is not used.

Voltage also runs from winding VI of transformer T_2 through contacts 6 and 13 on SC_{04} for heating tubes V_{02} and V_{07} of the second stages (Fig. 70). Voltage also runs from winding V in transformer T_2 to rectifier B_{21} using four D7G diodes. The voltage, after being rectified and filtered by capacitors 21 and 22, passes through contacts 6-7 and 13-14 to SC_{03} to the heaters of tubes V_{01} and V_{02} of the first stages of the amplifier (Fig. 70), which are connected in series. Winding IV is not used. /83

From winding III of transformer T_2, the voltage runs through contacts 12 and 13 on SC_{11} to rectifier B_{11} consisting of D7Zh diodes. After being rectified and smoothed by capacitor 16, the voltage passes to the stabilitrons V_{14} (SG1P) and V_{13} (SG2P). This voltage is the independent bias voltage, which is supplied to the grids of the amplifier tubes. Therefore the "plus" from rectifier B_{11} is connected to the common zero lead of the amplifier, connected to all parts of the mechanism which are screened and grounded to the chassis. This lead runs through the amplifier via contacts 1 on SC_{11} (Fig. 70) and SC_{03} (Fig. 71), and is linked to the "minus" of the principal rectifier B_{23-25} through the latter.

The cathodes of tubes V_{03} and V_{04} of the third cascades are connected to the minus of the stabilitron V_{14} through contacts 5 on SC_{11} (Fig. 71) and SC_{03}, while the grids of tubes V_{04}, V_{05} and V_{09}, V_{010} of the output stages (Fig. 70) are connected through the variable resistors 0107 and 0108. The cathodes of tubes V_{01}, V_{06} and V_{02}, V_{07} of the first two cascades are connected to the minus of stabilitron V_{13} through contacts 4 on SC_{11} and SC_{03}. Hence, a positive bias is applied to the grids of the tubes in the first, second and third stages, compensating for the negative potential which is formed on the resistors by the negative feedback, and forming a negative bias on the grids of the tubes in the output stage; the value of this negative bias changes the sensitivity (amplification).

Capacitor Data

0.1, 0.2	KSO-5, 500-B-3000-I	021, 022	KBGP-2, 600-A-0.1-II
0.3, 0.4	KSO-1, 250-B-51-II	013, 014	KBGU-600, 0.01-II
05-012	KPG-MN-200-1-I	019	KE-2, 150/10 M
020	KE-2, 50/30 M	023	KSO-I, 250-5-55-II

Resistor Data

Channel I	Channel II	
	001-009	MLT-0.5, 510 kΩ I-A
010, 011	012, 013	MLT-0.5, 110 kΩ I-A
014, 015	016, 017	MLT-5, 39 MΩ I-A
018-020		MLT-0.5, 270 kΩ I-A
021	083	MLT-0.5, 820 kΩ I-A
022, 023	081, 082	MLT-0.5, 510 Ω I-A
024, 025	079, 080	MLT-0.5, 120 kΩ I-A
026		MLT-0.5, 180 kΩ I-A
027, 028	073, 074	MLT-0.5, 2.7 MΩ I-A
029	075	MLT-0.5, 510 kΩ I-A
030, 031	076, 077	MLT-0.5, 8.2 kΩ I-A
032, 033	071, 072	MLT-0.5, 220 kΩ I-A
034-035	068, 069	SP-III-OS-520 $\frac{\text{A } 0.5 \text{ W } 3.3 \text{ MΩ}}{\text{A } 1.0 \text{ W } 3.3 \text{ MΩ}}$
036	070	MLT-0.5, 1.5 MΩ I-A
037	067	MLT-0.5, 3 MΩ I-A
038, 039	065, 066	MLT-0.5, 510 kΩ I-A
040, 041	063, 064	MLT-0.5, 1 MΩ I-A
042, 043	056, 057	MLT-0.5, 2.2 kΩ I-A
044-047	058-061	MLT-0.5, 2 MΩ I-A
048-050		MLT-0.5, 270 kΩ I-A
051		MLT-0.5, 180 kΩ I-A
052	053	Wire-wound 1Ω ± 1Ω
054		PE-7.5, 100 Ω I-A
055		MLT-0.5, 52 kΩ I-A
062		MLT-2, 300 Ω I-A
078		MLT-0.5, 220 kΩ I-A
084	085	SP-I-OS-520 IV A I W, 470 kΩ
086, 087	088, 089	SP-III-OS-520 $\frac{\text{A } 0.5 \text{ W } 1 \text{ MΩ}}{\text{A } 1.0 \text{ W } 1 \text{ MΩ}}$ /84
090		MLT-1, 100 kΩ I-A
091		MLT-0.5, 360 kΩ I-A
092		MLT-0.5, 2 kΩ I-A
093		MLT-0.5, 100 kΩ I-A
094		MLT-0.5, 3 MΩ I-A
095 at 0100		MLT-0.5, 100 kΩ I-A
0101, 0102		MLT-0.5, 10 kΩ I-A
0103, 0104	0105, 0106	MLT-0.5, 100 kΩ I-A
0107	0108	SP-1-OS-520 IV A 2 W 1 MΩ
0110	0109	SP-1-OS-520 IV A 2 W 470 kΩ
0111	0112	PE-2.5, 500-1
0113	0114	MLT-0.5, 30 kΩ I-A
0115	0116	MLT-0.5, 430 kΩ I-A

Power Supply and Stabilizer

C_{11}, C_{15}	KE-2, 300/30 M	C_{21}, C_{22}	KE-2, 30/500 M
C_{12}, C_{16}	KE-2, 400/20 M	C_{25}	MBGTs-1-2-250-P
C_{13}, C_{14}	KE-2, 450/20 M	C_{29}	KE-2, 150/10 M
C_{23}, C_{24}	KE-2, 450/20 M	C_{110}	MBM-160, 0.05-1
C_{28}	KE-2, 30/50 M	C_{111}, C_{112}	KSO-5, 500-B-5100-1
C_{30}, C_{31}	MBGP-2, 300-4-P		
R_{11}, R_{12}, R_4, R_{17}	MLT-2, 2.2 kΩ 1-A		
R_{13}, R_{15}	MLT-2, 5.1 kΩ 1-A		
R_{16}	MLT-2, 1.5 kΩ 1-A		
R_{111}	MLT-0.5, 51 kΩ 1-A		
R_{112}, R_{113}, R_{114}	MLT-0.5, 30 kΩ 1-A		

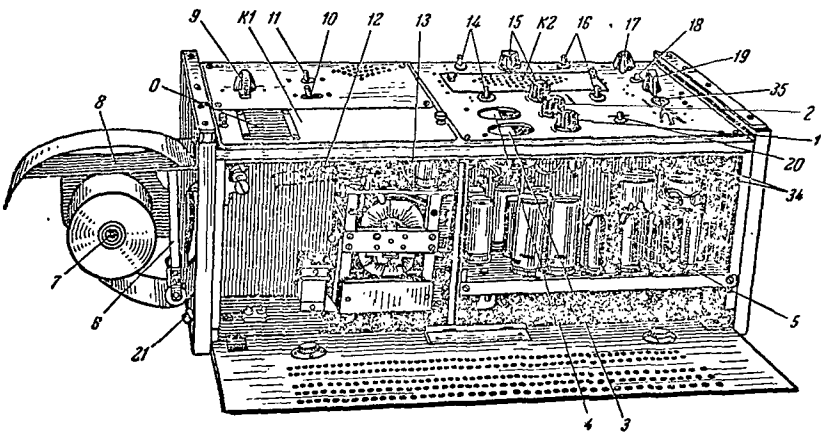


Fig. 73. View of EKPSCh-3 Electrocardiograph With Front of Cabinet Removed.

A general view of the EKPSCh-3 electrocardiograph (one of the first models) is shown in Figure 72. The apparatus is contained in a metal cabinet with removable sides. The top (lid) is used as a control panel. A view of the apparatus with the sides removed is shown in Figures 73 and 74. The control panel has two removable lids: lid K , which provides access to the recording section (there is a window O in the lid for watching the recording) and a lid K , which provides access to the amplifier tubes. There is a knob R on the side of the apparatus. On the left rear side (Fig. 73) is a window for the folding section 8 of the paper-transport mechanism. In the position indicated in Figure 73, the paper supply can be replaced (a new spool is mounted freely on axle 7 and the /85
paper is fed along shelf 6 so that its end protrudes about 5-10 cm). The folding part is then swung around and into the cabinet, so that shelf 6 on which the paper travels is immediately below pens 12. In this position, the folding part is held in place by retainer 21.

On the opposite side of the cabinet (Fig. 74) are sockets 31

and 30 for connecting cable 28 with the leads from electrodes and attachments, as well as socket 25 for attaching the ground wire. Socket 30 for attachments is usually occupied by the short-circuiting plug. On the side of the cabinet, at the bottom, is socket 24 for connecting the line cord 23 (the figure also shows a lead 26 connected to the apparatus, along with clamp 27 for grounding); above it is a panel 22 with fuses. Next to the panel is the ballast tube 31, while to the right of it is power transformer 32, and above it electric motor 33. To the left are the resistors, capacitors, and other parts of the amplifier.

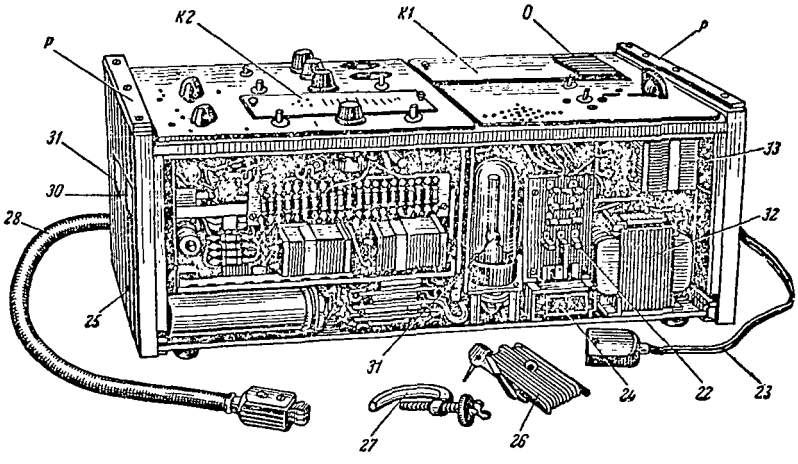


Fig. 74. View of EKPSCh-3 Electrocardiograph With Rear Cover Removed.

The top of the cabinet (Fig. 73) contains the controls (from left to right): switch 9 for the paper speed, line switch 10 and paper-transport mechanism 11, switch 14 for controlling the frequency band, indicators 3 and 4, knob 15 for controlling the amplification in the channels, knobs 1 and 2 for setting the zero line of the recording in channels I and II, toggle switch 16 for stepwise regulation of amplification, and button 20 for the damper. Knobs 17 and 19 for the lead switches controlling channels I and II are also located here, with button 18 of the calibrator between them; in front of these is socket 35 for connecting an oscilloscope.

From the front (Fig. 73), it is possible to have access to the vibrator 13 and the stabilitron section 5, in the upper right-hand corner of which are the potentiometers 34 for balancing the arms of the amplifier.

The amplifier-tube section is located in the middle of the cabinet, and is accessible by opening a cover closed by lid K_2 (Fig. 74).

The instrument as supplied by the factory corresponds to a single-channel apparatus (see § 3). This same section will also provide information on how to use the instrument for making electrocardiograms.

§ 5. VECTORELECTROCARDIOSCOPES /86

The vectorelectrocardioscope is intended for observing electrocardiograms or vectorelectrocardiograms on a screen (or photographing them by means of a separate camera).

At the present time, three types of vectorelectrocardioscopes are being produced: VEKS-01, VEKS-1P, and VEKS-3.

VEKS-01 is intended for observing electrocardiograms or plane vectorelectrocardiograms on a oscilloscope screen (or photographing them by means of a separate camera). The instrument can be used on 110, 127 or 220 V, and will operate at voltage deviations from nominal value within the limits -10 to +5%. The power consumption is 160 W.

The dimensions of the apparatus are 500 × 280 × 420 mm, and it weighs 28 kg.

The apparatus (see block diagram in Fig. 75) consists of a lead switch (LS), two amplifiers, a cathode ray tube, and a power supply, which in turn consists of a rectifier, a stabilizer for the rectified voltage, and a high-frequency generator with rectifier for feeding the anode of the tube. The instrument uses a type 2ZLMZ4 cathode ray tube, with long-term persistence and electromagnetic deflection. The size of the screen is 160 × 220 mm; the instrument is designed for use with a "Smena-4" camera, which can be mounted on a special stand in front of the screen.

Provision is made in this instrument for single scanning in both the vertical and horizontal axes of the screen. The scanning rate in the vertical axis is 45 ± 2 mm/sec, while it is regulated to 20 to 100 mm/sec in the horizontal axis. A calibrated voltage

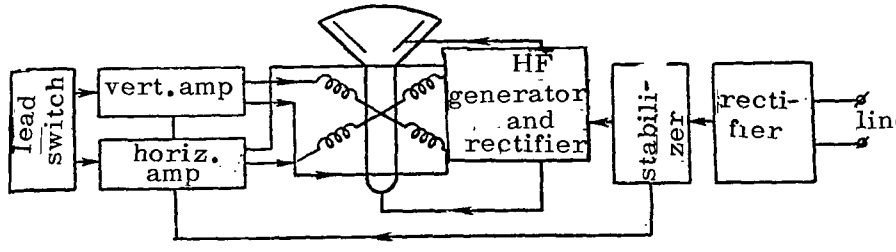
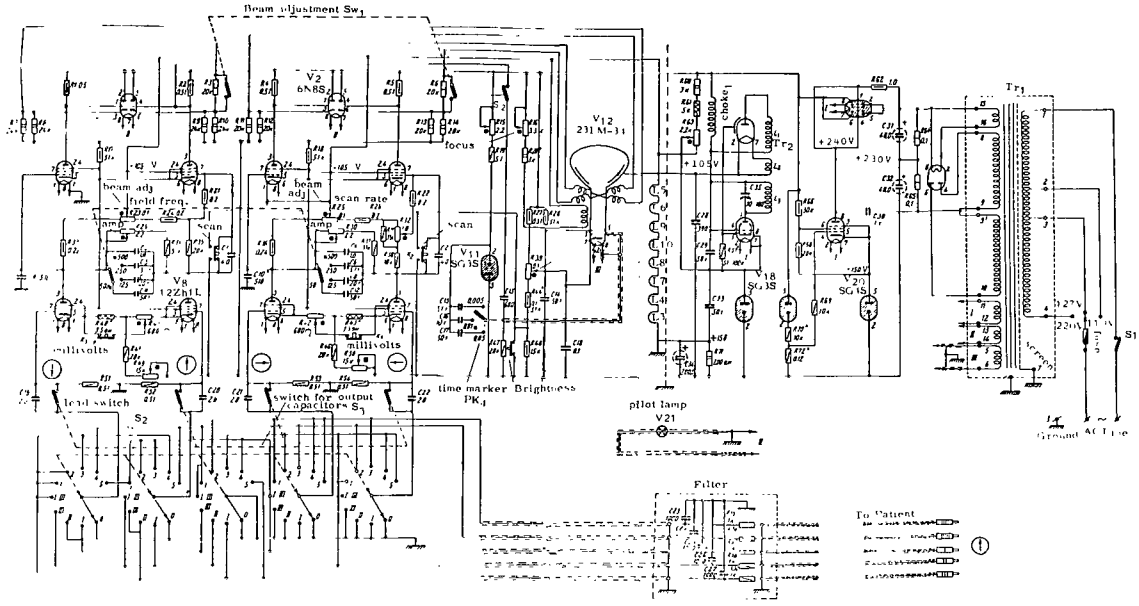


Fig. 75. Block Diagram of VEKS-01 Vectorelectrocardioscope.



Adjustments: ● Manual, Made on Control Panel ⌀ Inside Cabinet
* Adjust to Regulate

Note: Arrow in circle shows direction of beam deflection on the screen from the plus voltage applied to the input of a given amplifier

Fig. 76. Schematic Diagram of VEKS-01 Vector Electrocardioscope.

source (1 mV) is connected to the input of the amplifier for checking the regularity of amplification in the vertical and horizontal directions.

The time markings for the electrocardiograms are 0.05 sec (vertical pips along the line), while the time markings for vectorograms occur at 0.01 or 0.05 sec (shadings along the line).

To ensure the required accuracy in reproducing the processes under investigation with this apparatus, the pass band of the amplifier can be regulated within the following limits: 0-50, 0-125, 0-250, and 0-500 Hz.

The schematic diagram of the apparatus is shown in Figure 76. The diagram shows the nominal values of capacitance and resistance. The apparatus has two DC amplifiers, connected in a differential circuit. The vertical channel uses tubes V_8, V_7, V_4, V_3 and V_1; the horizontal channel uses tubes V_{10}, V_9, V_6, V_5, V_2. The operation of both channels is the same.

Biopotentials recorded with the aid of electrodes (five points of application for the electrodes can be used in recording vectorograms) reach the lead switch S_2 and then pass to the inputs of the /87
amplifier. Capacitors 19-22 are connected to the inputs, to prevent polarized potential differences of constant sign from reaching the amplifier; these differences are formed between the electrodes and the moist skin of the patient. Usually this potential difference is insignificant, so that the capacitors can be short-circuited or can be cut out by switch S_3.

The vertical-channel amplifier takes the voltage from the electrodes and applies it to the control grids of tubes V_7 and V_8 in the first amplifier stage. From the anodes of these tubes, the amplified voltage passes to the grids of tubes V_3 and V_4 in the second amplifier stage. The anode circuit of tubes V_7 and V_8 contain resistors 33, 35 and 24 and potentiometer 23, to the center tap of which is connected the power supply voltage. By means of resistor 23 (or resistor 25 in the horizontal channel), the amplifier is balanced. By changing the balance, the values of the constant component of the tube current is changed, which passes through the deflecting coils of the tube and determines the middle position of the beam on the screen. Hence, resistors 23 and 25 can be used to regulate the position of the beam on the screen.

A single sweep in the vertical or horizontal axes can be produced by pressing button K_1 or K_2. This closes the contacts which shunt capacitors 1 or 2, connected to the grid circuits of the corresponding tubes. This means that, e.g., a circuit is formed in the vertical amplifier which consists of capacitor 1, resistor 21 and resistor 35. Due to the presence of a voltage across the latter, formed by the constant component of the anode current of the tube, there will be a gradual charging of capacitors 1 (through resistor

21). This means that the positive potential on the grid will gradually increase, thus disturbing the balance of the amplifier and causing a gradual shift of the beam on the screen. The rate of shift and the corresponding rate of scan is determined by the time constant of the circuit $R_{21}C_1$. When the button is released, capacitor 1 is discharged and the beam on the screen return to the original position.

In the horizontal amplifier, charging of capacitor 2 (through resistor 22) is produced by the voltage across the fixed resistor 38 and the adjustable resistor 32. A change in the value of the latter causes a smooth change in the scanning rate.

When the scanning buttons are pushed, the brightness of the beam increases, since the button which closes the contact and shunts capacitor 1 simultaneously closes the contacts which shunt resistor 48 in the circuit which controls the beam brightness.

Between the anodes of tubes V_7 and V_8 there is a parallel circuit consisting of capacitors 3, 5, 7 and 11 and variable resistor 29 (in the horizontal channel, these are capacitors 4, 6, 8 and 12 and resistor 30). Switching the capacitors into the circuit (by means of switch S_1) establishes the desired frequency pass band of the amplifier, while the amplification of the channels is regulated by changing resistor 29 and 30.

From the anodes of tubes V_3 and V_4 (or V_5 and V_6), the amplified voltage passes to the grids of the output tubes V_1 and V_2, which serve as cathode repeaters: between the cathodes of each tube are connected the corresponding deflecting windings of the cathode ray tube.

To reduce the sensitivity of the beam deflection when setting up the apparatus, resistors 3 and 6 are connected to the output of the amplifier in series with the deflecting coils. After the instrument has been set up, and a transition to a normal observation cycle can be made, these resistors are shunted by the contacts of switch S_1.

Regulation of beam brightness of the cathode ray tube is accom-/88
plished by adjusting resistor 39; this changes the bias on the control electrode of the tube. The beam is focused by changing the current in the focusing coil by means of resistor 16.

Impulses for time marking are fed to the grid of output tube V_1 of the vertical amplifier, from a relaxation oscillator, consisting of a gas-filled tube rectifier V_{11}, capacitors 15, 16, and 17, and resistors 15, 19, and 47.

The anode of the cathode ray tube is powered by direct current from kenotron V_{13} from a high-frequency generator (frequency equals 310 kHz), connected to tube V_{16} with an oscillator circuit (see C_{35}-L_3) in the anode circuit.

The entire system is powered from a rectifier unit using kenotron V_{15} and filter capacitors 31-32, as well as a unit for stabilizing the rectified voltage. The latter operates with V_{14} and V_{17} tubes and stabilizers V_{18}, V_{19} and V_{20}. The filament wires in the amplifiers are arranged in series and powered by a stabilized voltage of 105 V. The power voltage for the input circuits of the amplifier is 300 V.

Fig. 77. Overall View of the VEKS-01 Apparatus.

The VEKS-01 apparatus (Fig. 77) is portable and mounted in a rectangular cabinet, the front of which serves as the control panel. On the panel, below the screen 1 of the tube (covered by a protective window), are the knobs for controlling the apparatus. In the upper part of the panel are the following. At the upper left are switch 2 and knob 3 for adjusting the time markings. In the middle are the knobs for controlling brightness 4, focus 5 and rate of horizontal scanning 6. At the right is switch 7 for complete and "compressed" shifting of the beam, and below it knob 8 for adjusting the frequency range of the amplifier. The lower panel has several controls: in the middle is lead switch 9 and below it button 10 for increasing the brightness when photographing the tube. On the sides are knobs 11 and 12 for adjusting the amplification, knobs 13 and 14 for adjusting the beam, buttons 15 and 16 for scanning, and buttons 17 and 18 for connecting the millivoltmeter; the ones on the left are for the vertical amplifier and those on the right are for the horizontal amplifier.

The cabinet is fitted with openings covered by lids, which provide access to the parts of the amplifier: the one in the front gives access to the tubes (on the right the horizontal, and on the left the vertical channel); the ones in back give access to the rectifier tubes (on the right) and the generator which feeds the anode of the tube (on the left). On the right, directly on the control panel, is a small window which permits disconnecting the input capacitors.

A general view of the apparatus with the cover removed is shown on Figure 78. All of the parts of the apparatus are divided among three units: on the top level is the cathode ray tube, while /89

on the bottom is the amplifier section (in front) and the power supply (in back). The following are the explanations of the numbers in Figure 78: (1) cathode ray tube; (2) deflecting coils; (3) focusing coil; (4) switch for capacitors at input of amplifiers; (7) amplifier tubes; (5 and 6) power supply tubes.

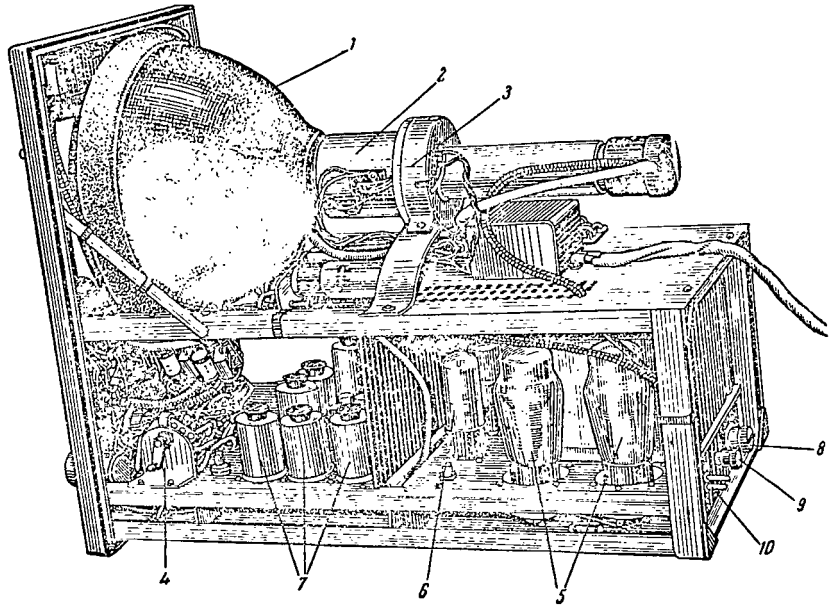


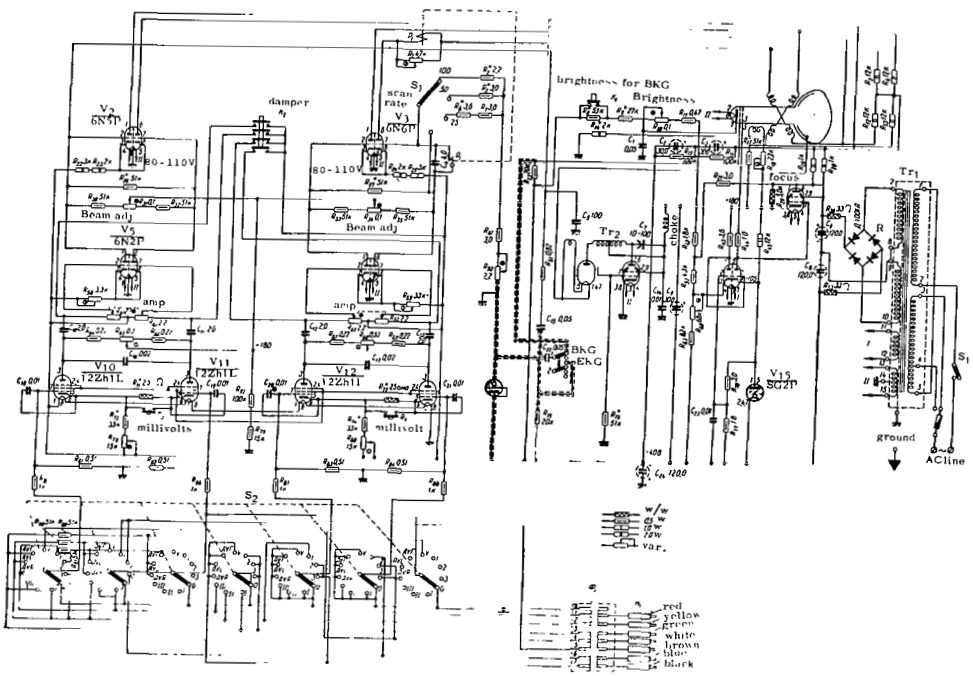
Fig. 78. Location of Parts (Internal View) in the VEKS-01.

On the back of the chassis is the fuse panel-switch 8 for 127/220 V, grounding knob 9 and plug 10 for connecting the line cord.

In 1957, the VEKS-01 was improved. The size and weight of the instrument were considerably reduced by using a small screen cathode ray tube (12LM31, 90 × 80 mm), bantam tubes, and other small size components. The instrument is now being produced as the VEKS-IP (portable). The symbols and technical data are essentially the same as those of the VEKS-01. There are certain differences, however:

1. The VEKS-1P has seven electrodes, which are applied to the patient, thus making it possible to carry out electrocardiographic studies (with standard, amplified, and unipolar leads) as well as vectorelectrocardiographic studies by means of the Akulinichev method using plane projections and Grishman's method using the cube system.

2. The apparatus makes it possible to have a periodic scanning along the horizontal axis of the screen at three speeds: 25, 50 and 100 mm/sec.



1. Resistor values 2. Method of adjustment 3. To improve quality in some versions of this instrument, small changes may be made in the circuit aid design 4. Voltages measured relative to chassis

● Knob on control panel ◑ Setting on back of cabinet ◐ Setting inside cabinet ✲ Resistance to be adjusted

Fig. 79. Schematic Diagram of VEKS-1P Vectorelectrocardioscope.

3. The time markings for both the electrocardiograms and the vectorelectrocardiograms are given every 0.05 sec.

4. The instrument does not have any setting for changing the frequency range.

5. The power consumption is 130 volt-amperes.

6. The dimensions of the instrument are 200 × 280 × 420 mm /90
and it weighs 15 kg.

The schematic diagram of the VEKS-1P is shown in Figure 79. It has two separate differential three-stage amplifiers for amplifying signals in both the vertical and horizontal axes of the cathode ray tube. The first stage (12Zh1L tubes, marked V_{10}, V_{11}, V_{12}, V_{13} in the diagram) are connected in the amplifier circuit with resistors; the second stage (6N2P tubes, marked V_5 and V_6 in the diagram) and the third stage (6N5P tubes, V_2 and V_3 in the diagram) serve as DC amplifiers. The anode circuits of the output tubes contain the deflecting coils of the cathode ray tube. To improve the characteristics, these coils are shunted by resistors 3-4 and 12-13.

The scanning of the process under investigation in the horizontal direction is accomplished by charging capacitor 4, connected to the grid circuit of output tube V_3 of the horizontal amplifier. In the zero position of the switch knob S_1, for setting the scanning rate, capacitor 4 is shunted by the contacts of the switch. When the switch S_1 is moved into one of the operating positions, a circuit is formed for charging capacitor 4 with the voltage across resistors 35 and 34 (its right-hand portion). The charge passes through resistors 2, 5 or 6 and 7 together, thus achieving a stepwise regulation of the scanning rate. Depending on the charge in capacitor 4, the voltage in the tube circuit increases and there is a corresponding increase in the constant component of the current through the tube. This produces a gradual shifting of the beam in the tube in the horizontal direction. When the current reaches a maximum, corresponding to the maximum shift of the beam, relay R_1 operates; the contacts of the latter shunt capacitor 4. The latter discharges rapidly, the current in the tube falls, and the beam returns to its original position in the tube. The contacts of the relay close and the process which produces a gradual shift of the beam is repeated until the knob of the switch S_1 is returned to the zero position.

Regulation of amplification in the channels is accomplished with the aid of resistors 61 and 62, connected to the anode circuit of the input tubes. By means of the variable resistors 65 and 68, connected to the anode circuits of the first stage, the arms of the amplifying channels are balanced. The sensitivity of the channels is checked by pressing buttons K_3 or K_4, which sends a calibrating voltage of 1 mV into the grids of the tubes in the first stage; this voltage is formed by resistors 71 or 72.

Button K_2 of the damper connects capacitors 10-13 to the minus side of the circuit, thus considerably reducing the time required to charge them and making it possible to begin a new recording process when the lead switch S_2 is adjusted.

The time marker consists of a thyratron V_{14}, capacitors 5, 15, 22 and resistors 28, 41, 50, 51, 75. Regulation of beam brightness is accomplished with the aid of resistor 10. The brief increase in brightness required for making photographs of vectorograms is accomplished by shunting resistor 8 with button K_1. The beam is focused by changing the value of resistor 18, connected in the circuit of the focusing coil of the cathode ray tube.

The anode of the cathode ray tube is powered by direct current from kenotron V_7, from a high-frequency generator consisting of tube V_8.

The voltage for powering the amplifiers, the high-voltage generator, the time marker, and other parts of the components of the apparatus, is obtained from rectifier B, consisting of a bridge circuit using semisonductor diodes D1001A, with a voltage relative to the chassis of +180 and -40 V; this output is fed to a stabilizer consisting of tubes V_4, V_3, and V_{15}. Tube V_4 is a regulator, /91 V_9 is an amplifier and V_{15} is a stabilitron. The regime of the amplifier tube is set by resistor 60.

An overall view of the apparatus is shown in Figure 80. The instrument is mounted on a chassis, and covered by a metal cabinet whose front serves as the control panel. The upper part of the latter is occupied by the cathode ray tube screen; it is covered by a transparent shield marked with a calibrated grid 13. Below the screen opening are two threaded bushings 14, onto which the supports for the camera stand are screwed. In the upper /92 left part of the panel is switch 1 for the time marker, and in the right-hand corner is lens 2 of lamp L_{14} for the time marker, indicating that the apparatus is working.

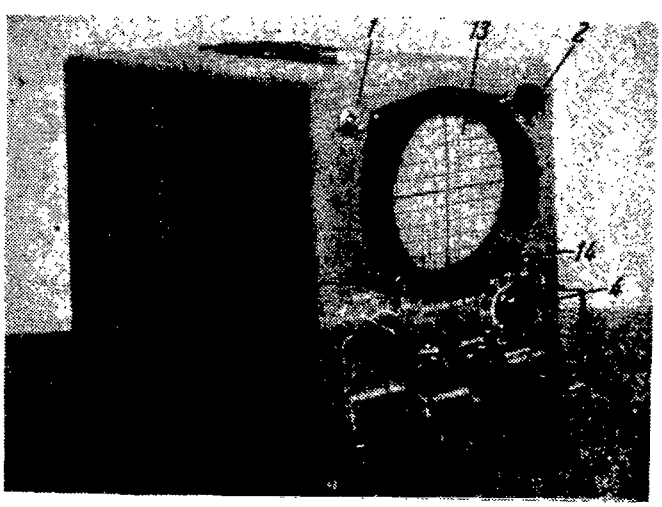


Fig. 80. Overall View of VEKS-IP.

Below the screen of the tube are the following: knob 3 for adjusting the scanning rate, button 5 for increasing brightness, knob 4 for the lead switch, and knobs 6 and 7 for adjusting the amplification, as well as knobs 8 and 9 for adjusting the beam for the vertical and horizontal

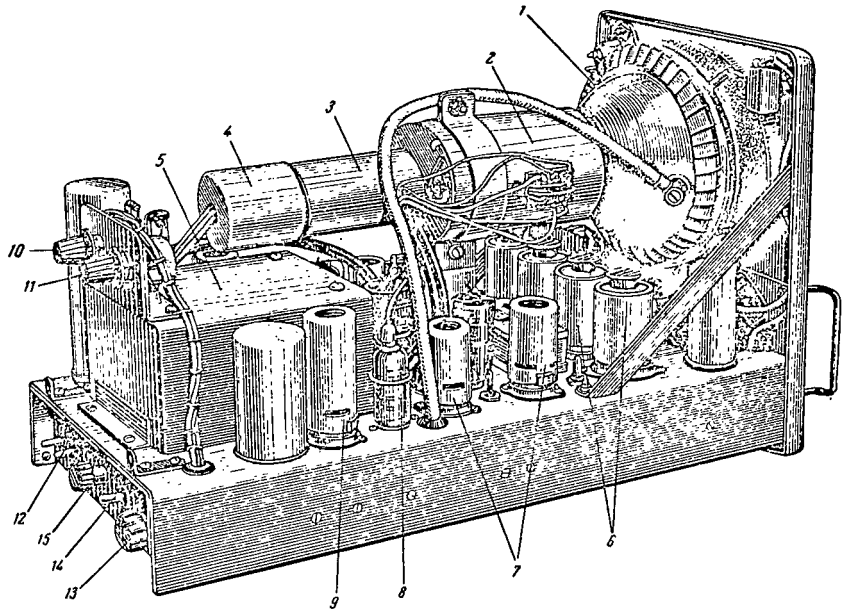


Fig. 81. Location of Parts in VEKS-IP.

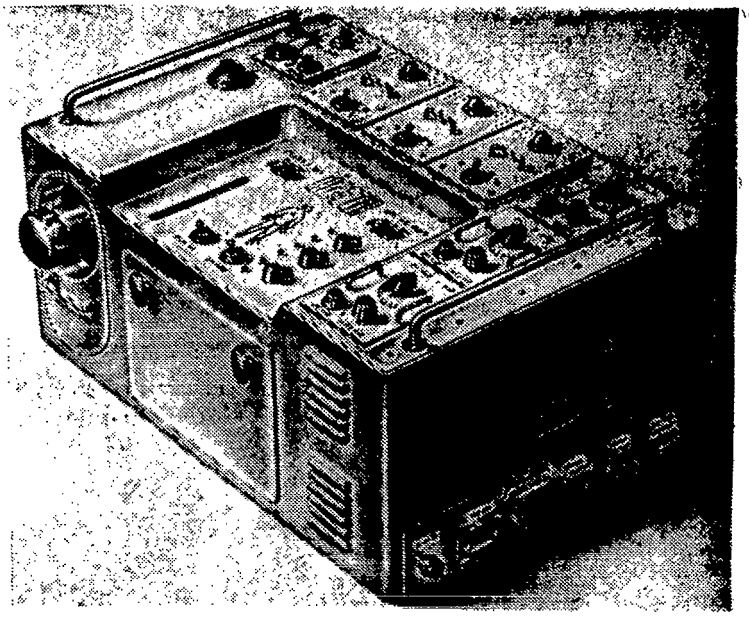


Fig. 82. Overall View of Three-Channel Electrocardiograph, Model 072.

channels. Between the latter are buttons 10 and 12 for delivering the calibrating voltage of 1 mV and button 11 of the damper.

On the right-hand side of the chassis is a socket for an eight-contact plug which is attached to the cable with the leads from the electrodes.

Figure 81 shows an overall view of the apparatus with the cabinet removed. In the upper part of the instrument are the following: cathode ray tube 1, with deflecting coils 2 on its neck, focusing coil 3 and socket 4 for attaching the power leads. The chassis contains power transformer 5, amplifier tubes 6 and 7, power supply tubes 8 and 9, and other parts.

At the rear of the chassis are knobs 10 and 11 for adjusting the brightness and focus of the beam; below them on the chassis is the line switch 14, the fuse panel and switch 13 for 127/220 V, grounding clamp 15, and plug 12 for connecting the power cord.

The VEKS-3 instrument is intended for special investigations. It uses a 31LOssV cathode ray tube with electrostatic deflection, and it has a screeen measuring 180 × 240 mm. The instrument has three amplification channels, which operate with DC amplification, and an electronic switch which can be used to set the instrument to two basic operating regimes: (a) simultaneous observation of electrocardiograms /93 from three leads and (b) spatial (three-dimensional) vector-electrocardiography, in which three curves are observed simultaneously, constituting projections of the vectorelectrocardiogram of the heart on three mutually perpendicular planes.

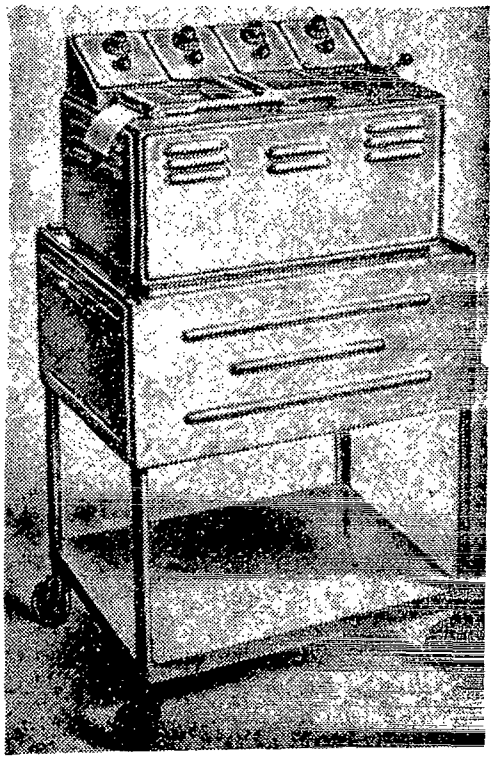


Fig. 83. Overall View of EKG4-01 Electrocardiograph.

§ 6. MULTICHANNEL ELECTROCARDIOGRAPHS

Various complicated instruments are produced by the industry for functional studies of the cardiovascular system. A great many of them have been devised by the designers of the "Biofizpribor Office".

Of these special instruments, we should certainly mention the multichannel de-

vices which make it possible to simultaneously record electrocardiograms from three or more leads simultaneously while recording other physiological processes: cardiac sounds, arterial or venous pressure, pulse rate, filling of the vessels with blood, etc.

The Model 072 (Fig. 82) is a three-channel electrocardiograph designed for use with line voltage and using photoelectric recording on paper. An interesting feature of the apparatus is its unit construction: each amplifying channel has a separate power supply and is built in the form of an independent unit which is connected by cables to the other parts of the instrument. This makes it much easier to replace certain parts during its operation. The five-channel electrocardiograph (type EKG5-01) is similar in design.

The EKG2-01 (Fig. 83) and EKG4-01 electrocardiographs are two- and four-channel instruments for continuous ink recording on paper, and are designed to be used with AC power sources. These devices are generally similar in design to those described earlier with ink recording.

The following additions should be made to the electrocardiographs mentioned above:

(a) The FKG-01 phonocardiograph. This instrument makes it possible to record three phonocardiograms simultaneously.

(b) The BDKG-01 ballistodynamocardiograph. In ballistocardiography, the insignificant movements of the body are recorded which are produced by the action of the reactive forces which arise due to the action of the heart and the movement of the blood in the vascular system. To record these variations, the patient is placed on a large horizontal movable platform. Insignificant changes or oscillations of the platform are recorded by means of a highly sensitive sensor. In dynamocardiography, a similar method is used to record the change in the partial center of gravity of the rib cage in connection with the distribution of the blood during the cardiac cycle. This instrument makes it possible to record ballistocardiograms, as well as two dynamocardiograms: the longitudinal and transverse. /94

(c) The RG1-01 rheograph. This instrument is intended for recording oscillations in the manner in which vessels in certain parts of the body are filled with blood, by recording changes in the total electrical resistance of a circuit between electrodes applied to the part of the body being studied.

(d) The SG2-01 sphygmograph. This makes it possible to record pulse curves for various arteries and peripheral veins, as well as to record the volume arterial pulse in the extremities (plethysmography).

(e) The EM2-01 electromanometer. This is used in surgery for recording the blood pressure in the chambers of the heart and the large vessels by means of catheters inserted into them.

CHAPTER III

DIRECT-CURRENT AND LOW-FREQUENCY ELECTROTHERAPEUTIC APPARATUS

PART 1

GENERAL CLASSIFICATION OF ELECTROTHERAPEUTIC METHODS AND DEVICES

Electrotherapeutic devices constitute an important division /95
of the machines used in physical therapy. For a better understanding of both the common features and the differences in the purpose and design of individual types of instruments, it is necessary to classify them. Various methods of classification have been devised for the machines used in physical therapy, and consequently for electrotherapeutic apparatus as well. The most suitable method is their classification according to the physical factors by means of which they act on the organism.

From the historical point of view, electrotherapeutic apparatus, including devices for electrodiagnosis, can be divided into two main groups: (a) apparatus using direct current and low frequency, and (b) apparatus using high-frequency current. The first group includes devices for galvanization, ionogalvanization, faradization, the "four-chambered bath", electrodiagnosis and electrogymnastics of the muscles, and franklinization. The second group includes apparatus for diathermy, general and local d'arsonvalization, and UHF therapy. A similar division can be made from the standpoint of application, since devices in each of these groups have much in common.

Division along the line of low and high frequency also reflects a definite difference in the electrical phenomena employed for treating the organism; in the first case it is direct current, induced (faradic) current and static electricity; in the second case it is high-frequency electrical oscillations. The same principle can be applied to a more detailed classification.

We should begin by making some remarks regarding the use of the names applied to the different methods of electrotherapy and to the corresponding devices. A great many of these names have been retained from very remote times and do not have much meaning from

the modern point of view. It is only in medicine, e.g., that direct current is called galvanic; current obtained by means of an induction coil, is called faradic, etc. There is no logical basis for the names of the therapeutic methods employing these varieties of electricity, such as "galvanization" "faradization", etc., so that the names of the devices using them do not make much sense either: apparatus for galvanization, apparatus for faradization, etc.

Some of the methods and devices are named after scientists who /96 are famous for their work in the field of electrotherapy or even basic electricity. For example, "d'arsonvalization" is named after the physician and physicist d'Arsonval, who proposed this method of high-frequency therapy, and "franklinization" is named after the physicist Franklin,who was famous for his work with static electricity.

In some cases, the therapeutic methods and devices were named after the physical effect which distinguishes them; e.g., "diathermy", which can be translated as "thorough heating", while in other cases they were named after the physical force itself, e.g., "UHF electrical field therapy", or "UHF therapy" for short, etc. Names of this sort are more acceptable, but they also require a certain degree of explanation..

The reason that such names have persisted in practice is mainly because they are so short. To replace antiquated terms by new ones which are more correct would in many cases require more complex formulations. For example, the name "apparatus for four-chambered baths" would have to be changed to "apparatus for galvanization with baths for the extremities" (abbreviated AGBE) etc.

In 1950, A. N. Obrosov and N. M. Liventsev at the State Institute of Physical Therapy devised a method of classifying electrotherapeutic methods, based on the physical characteristics of the force acting on the organism (classification is shown in the table).

All of the methods are divided first of all into two basic groups. The first contains the methods in which the effect on the organism is achieved by means of an electrical current with certain characteristics, therefore requiring application of electrodes to the surface of the body. The second group consists of those methods in which the effect on the organism is accomplished by means of a field, so that there is no necessity for electrodes to be applied to the body.

Understandably, this classification (as is true of any classification method) involves certain simplifications and schematizations of phenomena. In particular, the division of methods of electrotherapy on the basis of whether a "current" or a "field" is used is very arbitrary, since a current and a field involve very closely related phenomena. However, this division differentiates between the methods which require actual application of electrodes to the body in one case and the absence of a need to

do this in the second.

The first group is subdivided into three second-order categories depending on the type of current: direct, low-frequency alternating, and high-frequency alternating current.

The methods in the second group are similarly divided according to the nature of the field which produces the effect. This is primarily a very general form, an electromagnetic field which can be used both as an induction field and as a radiation field. The corresponding methods (general d'arsonvalization and microwave therapy) are located in the table in the middle of this group. On both sides (i.e., above and below) are the methods which use mainly one of the components of an electromagnetic field: either the magnetic or the electrical. Finally, at the edges of this group in the table are those methods in which the effect on the organism is accomplished by means of a steady field: on the one hand, a magnetic field, and on the other hand, an electrical one.

The criterion used to make the third-order division in this /97
system of classification is whether or not the phenomena are constant or pulsed (i.e., the shape of the brief pulses or surges which are distributed relative to time). This is also of great significance for the effect of a particular physical agent on the organism. In the case of a steady treatment, the total amount (dose) given during a treatment is much greater than with a pulsed form, but in the latter case much higher instantaneous values of intensity are permissible. In many cases, constant or pulsed application of the same physical agent produces different physiological reactions in an organism. Therefore we can expect that the therapeutic affect in these cases will also differ.

Let us turn to the details of the individual methods. In galvanization, the effect produced on the organism by a constant steady electrical current of relatively small intensity is employed. In ionogalvanization, this same effect is used for simultaneously applying ions of curative substances to the organism.

Electrostimulation, electrodiagnostics, and faradization involve the action on the organism of a pulsed current of a different type. This group of methods also includes the so-called diadynamic currents, discovered by the French physician Bernard, and also the method of so-called electronarcosis, devised by Soviet physicians as a method of using pulsed current to affect the central nervous system.

Alternating sinusoidal current of low frequency (50-100 Hz) /98
is not used in a constant regime for electrotherapy. High-frequency alternating current (3000-5000 Hz), modulated in amplitude by low-frequency pulses, is used. One of the most widely employed forms of this method is the so-called interference current method proposed by the Austrian physician Nemek.

TABLE 8. CLASSIFICATION OF THE PRINCIPAL METHODS OF ELECTROTHERAPY ON THE BASIS OF THE PHYSICAL CHARACTERISTICS OF THE FACTOR ACTING ON THE ORGANISM

Principal Factor Acting on the Organism	Characteristics of the Factor	Operating Regime of the Factor	Name of the Method
Group I: effect of currents applied through electrodes in contact with the body	Direct Current	Constant	Galvanization, iono-galvanization
		Pulsed	Faradization. Electrical stimulation and electrodiagnostics. Diadynamic currents of Bernard. Electronarcosis
	Low-frequency alternating current	Constant	———
		Pulsed	Interferential currents
	High-frequency alternating current	Constant	Diathermy
		Pulsed	Local d'arsonvalization
Group II: action of a field without electrodes in contact with the body	Constant magnetic field	Constant	During radiation
		Pulsed	———
	Magnetic component of an induction field	Constant	Inductothermy
		Pulsed	———
	Electromagnetic field of induction	Constant	———
		Pulsed	General d'arsonvalization
	Electromagnetic field of radiation	Constant	Microwave therapy
		Pulsed	———
	Electrical component of induction field	Constant	Therapy with a UHF electrical field
		Pulsed	Pulsed UHF therapy
	Constant electrical field	Constant	Franklinization (static shower).
		Pulsed	During irradiation

High-frequency alternating current is used in a constant regime for diathermy (therapeutic and surgical).

Local d'arsonvalization is also included among the methods using alternating electrical current at high frequency. In local d'arsonvalization, the effect on the organism (primarily through the surface of the skin and the mucous membranes of certain areas) is applied by a high-frequency electrical discharge of varying intensity, obtained by means of a contact electrode of capacitor type, filled with rarefied gas.

A peculiar feature of local d'arsonvalization is the pulsed nature of the high-frequency discharge.

Let us now examine the method in the second group. A high-frequency electromagnetic field in the form of directed electromagnetic radiation ("radiation field") is used in a continuous regime in microwave therapy (on the decimeter and centimeter wavelengths).

An electromagnetic induction field, formed in an oscillator circuit, is used for general d'arsonvalization.

The magnetic component of an induction field in a continuous regime is used for inductothermy, which is also somewhat inaccurately referred to as short-wave diathermy. The principle of the method involves the action of a high-frequency magnetic field on the organism, primarily to produce heat by the eddy currents formed in the tissues of the organism.

The electric component of the induction field in a continuous regime is used in the very widely employed method of UHF electrical-field therapy, or UHF therapy for short. In recent years, the State Institute of Physical Therapy has also developed a method for using a UHF electrical field in a pulsed regime: this is called pulsed UHF therapy.

The action of a direct electrical current on an organism is employed in franklinization or the static shower, which is the oldest method of electrotherapy.

A method of using a pulsed direct electrical field has been developed at the Tomsk Medical Institute. It has not been widely employed.

The use of a constant magnetic field has not been widely employed, but a similar method has been devised at the Perm Medical Institute and, in the opinion of its inventors, it is effective in some cases. At the present time, further experiments are in progress in this field.

We have presented this general classification of the methods

of electrotherapy here in the introduction, since it will determine the organization of the material to be presented later on.

For a better understanding of the principles involved in classification of the methods of electrotherapy into a general system, we recommend that the reader return to this problem once again after reading the corresponding chapters and that he familiarize himself with the methods themselves in greater detail.

PART 2

/99

APPARATUS FOR DIRECT-CURRENT THERAPY

§ 1. PHYSICAL PRINCIPLES AND METHODS OF APPLYING GALVANIZATION AND IONOGALVANIZATION

The tissues of the human body consist primarily of albuminous colloids, which are poor conductors of electrical current. However, in most tissues these colloids contain a certain amount of dissolved mineral salts (electrolytes), which are good conductors of electrical current. The content of dissolved salts in a given tissue improves its electrical conductivity as a whole.

The best electrical conductivity is shown by the fluids in the organism (blood, lymph, etc.), as well as the tissues which are usually suffused by tissue fluids, such as the muscle tissue. The tissue fluids, which resemble blood plasma in their structure, represent a biological mixture of organic and inorganic dissolved substances. Of the latter, the most important is sodium chloride. The total content of salts in the tissue fluids includes a concentration of about 0.85% sodium chloride (isotonic physiological solution).

For an isotonic (8.5 g/l liter of water) solution of sodium chloride, the specific electrical conductivity for direct current (specific electrical conductivity is calculated for 1 cc of solution and is measured in $ohms^{-1}$) has the following values at different temperatures (Table 9).

TABLE 9

Temperature °C	Electrical conductivity $ohms^{-1} \cdot cm^{-1}$
0	0,0083
18	0,0132
25	0,0152
37	0,0192
50	0,0234

These data characterize the order of magnitude of electrical conductivity in tissue fluid.

The least satisfactory conductors are the nerve tissue (brain), connective and fatty tissue. The coarse-fibered connective tissue, dry skin, and especially bone stripped of the periosteum are among the very worst conductors and may even be considered dielectrics.

The specific electrical conductivity (in $ohms^{-1} \cdot cm^{-1}$) of various tissues in the organism, for direct current, can be characterized by the following general data (Table 10).

TABLE 10

Cerebrospinal fluid	0.018
Blood serum	0.014
Blood	0.005
Muscle tissue	0.006
Internal organs	0.003-0.002
Brain and nerve tissue	10^{-3}-10^{-4}
Fatty tissue	10^{-4}-10^{-5}
Dry skin	10^{-6}-10^{-8}
Bone without periosteum	10^{-8}-10^{-10}

In estimating the electrical conductivity of various parts /100
of the organism as a whole, and especially in determining the propagation pathways for current between the electrodes (which are usually applied to the surface of the body), it is necessary to keep in mind that it is the content of the tissue fluid which determines the electrical conductivity of the tissues and organs and that the current between the electrodes does not travel the shortest distance as it does in a uniform substance, but rather follows the pathways of the tissue fluid, blood and lymph vessels, the tissues which contain the fluid surrounding the nerve trunks, etc. This means that the propagation of currents in a living organism can be very complex and may involve tissues which are quite remote from the place where the electrodes are applied.

The electrical conductivity of the skin is dependent to a considerable extent on the state of its surface; dry, particularly rough skin conducts practically no electrical current, while thin, young skin, especially when covered with sweat, is a good conductor. Moist skin or skin with a damaged layer of horny epidermis are also good conductors. Hyperemia and especially edema of the skin considerably increases electrical conductivity.

From the above, we can conclude that the total resistance of a portion of the organism for a given position of the electrodes is determined mainly by the resistance of the skin layer and to a lesser degree by the layer of subcutaneous cells. The resistance of tissues located further inside the body, especially with regard to the possibility of the existence of current pathways in them,

is relatively low. In this regard, the value of the total resistance between the electrodes applied to the surface of the skin depends primarily on the condition of the skin and the area of its contact with the electrodes, and is dependent only slightly on the distance between the electrodes.

In considering the conditions for passage of a direct current through the tissue of the organism, it is necessary to consider the phenomena of electrolytic polarization, which can arise both within the tissue being subjected to the action of an electric current and on the surface of the electrodes applied to the skin.

Within the tissue, due to the presence of various semipermeable membranes in them, there will be local accumulations of ions which form space charges of one sign or another. Potential differences arise between the charges, which are opposite in sign to the applied potential.

The products of the electrolysis of these solutions, located in the tissues between the electrodes (primarily sodium chloride), form gas bubbles on the surface of the electrodes, which reduce the active surface of the electrode and can also form galvanic vapors from the electrode material, whose e.m.f. is directed against the applied potential.

All of this means that the resistance of electrolyte solutions and especially the tissues of the organism is much higher with respect to direct current than it is to alternating current, when these phenomena are practically nonexistent.

Galvanization involves the action of a direct current of relatively low intensity on a given region of the body. Current is led from the supply to the tissues by means of wires and flat metal electrodes, applied to the surface of the body. Lead is generally used for the electrodes because it is so soft and flexible and also because it is relatively inert from the physical and chemical standpoints. Oxidized by the action of moisture, the lead is covered by a thin film of oxide which prevents further corrosion. In addition, it forms a very inert ion, so that lead ions almost never /101
participate in the process of current formation between the electrodes.

However, the application of metal electrodes directly to the skin is not advisable. The products of electrolysis of the principal tissue electrolyte, a solution of sodium chloride, which are formed on their surfaces (sodium hydroxide and hydrogen are formed at the negative electrode and hydrochloric acid and oxygen are formed at the positive electrode) will have a caustic effect on the skin.

To prevent this, the surface of the skin below the electrode is covered by a piece of cloth (carefully moistened cotton, flannel or fustian) about 1 cm thick. This cloth is simply moistened with

warm water or as we shall see below, some medicinal solution. This covering must have an area somewhat larger than that of the electrode, and should not extend more than 1 cm in all directions beyond it. When a moist covering of this sort is applied, the substances produced on the surfaces of the metal electrodes remain in the cloth and do not touch the skin. After use, the cloths are washed with water and sterilized by boiling.

The electrodes and cloths are held to the surface of the skin so that the area to be treated is located between the electrodes. Both transverse and longitudinal positions of the electrodes are used. The latter are held in place by elastic straps. Figure 84 shows application of the electrodes for galvanization (or ionogalvanization) using transverse (a) and longitudinal (b) application of the electrodes. The following are shown in the figure: (1) cloth; (2) electrode (lead strip); (3) elastic straps to hold the electrodes.

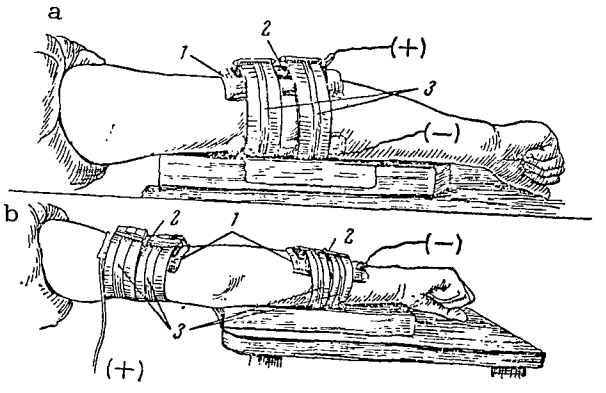


Fig. 84. Location of Electrodes for Galvanization or Ionogalvanization. (a) Longitudinal; (b) Transverse.

The electrodes are made of sheet lead, 0.5-0.7 mm thick. The assortment of electrode strips and cloths shown in Table 11 is recommended.

In addition, it is also necessary to have a supply of electrode strips and cloths of special shapes, e.g., circular ones with a hole in the center (for the mammary glands), kidney-shaped ones with three parts (for the facial nerves), a flanged electrode according to Scherbach, etc.

TABLE 11 /102

Dimensions of electrode in cm	Dimensions of cloth in cm	Dimensions of electrode in cm	Dimensions of cloth in cm
4×6	6×8	12×20	14×22
6×10	8×12		16×24
8×12	10×15	16×24	18×28
	12×16		20×30

The shape and dimensions of the electrode and cloth are selected in accordance with the size of the area of the body being subjected to the action of the current. The area of the cloth is selected so that the current passing through 1 cm^2 of it is 0.1-0.2 mA; high current density produces unpleasant sensations. (Normally these sensations are felt as a gentle warmth and burning, similar to the sensations produced by a weak mustard plaster).

The sensitivity of mucous membranes to direct current is much greater than the sensitivity of the skin, so that the current density in this case is reduced to 0.02-0.03 mA/cm^2.

The area of the metal strip can be made much smaller when the thickness of the cloth is adequate, since the current disperses equally all through the cloth. In particular, e.g., when using the collar method (according to Scherbach), it is necessary only to place two or three indivual lead strips, each measuring 4 × 5 cm, and connected to a common lead, over the entire surface of the cloth covering.

The current density is not uniform in either the metal strip or the cloth. It is greater at the edges, and at all irregularities or projections, e.g., on creases. Therefore the cloths must be periodically smoothed with a flat iron, and the lead strips must be smoothed out with a special roller on thick glass or a steel plate. The surface of the lead strips, oxidized and contaminated during use, must be cleaned periodically with emery cloth. Corroded strips must be replaced by new ones. Recently, tests have been made to determine the possibility of making electrodes out of a special flexible plastic material which possesses high electrical conductivity and can replace the lead. The electrodes are made in the form of strips and are used in the same way with cloth coverings.

The electrodes are connected to the apparatus by wires which are either soldered to the lead strips or attached to them by special clips. The leads are made of flexible (stranded) wire, 0.75-1 mm^2, with plastic or rubber insulation.

The resistance of the circuit between the electrodes differs within very wide limits in various procedures. This resistance comes from the intermediate resistance between the electrodes and the cloth, the resistance of the cloth itself, the intermediate resistance between the cloth and the skin, and finally the resistance of the subjacent tissues through which the current passes.

It should be noted that the intermediate resistance between the cloth and the skin, as well as the resistance of the skin itself, depend on the current density and the duration of its application. With prolonged contact between the skin and a damp cloth, the surface of the skin also becomes damp and the resistance of the horny layer of the epidermis decreases appreciably.

In many local applications to the trunk and extremities, using a cloth area of 100-200 cm^2 and a current of 10-20 mA, the resistance to direct current is 500-1000 ohms on the average; in the /103
case of small pieces of cloth and a current of 4-5 mA, this can increase to 2000-3000 ohms. In the case of orbital-occipital application of the electrodes, at a current of 1-2 mA, the resistance reaches 5000 ohms. Therefore, the source of the current used for galvanization in local applications must provide potentials up to 40-50 V and currents of 25-30 mA.

The movement of ions in solutions under the influence of an electric field (ionophoresis) or any larger electrically charged particles (electrophoresis) is used in electrotherapy for introducing therapeutic substances into the body. Therefore, in addition to the medicinal action of the substances introduced into the body, the action of the electrical current itself on the tissue is employed; this is called ionogalvanization.

To introduce medicinal substances into the body by means of an electrical current, the cloths beneath the electrodes are moistened with a solution of this substance. Medicinal substances are introduced into the organism according to the sign of the charge which the particles of these substances assume when dissociated in solution: from the positive electrode, the ions of metals as well as particles of complex substances which are positively charged in solution are introduced into the body (quinine, novocain, etc.); the negative electrode is used to introduce ions of acid radicals, as well as particles of complex materials which are negatively charged in solution (sulfidine, penicillin, etc.).

Table 12 lists the substances most often used for ionogalvanization, with an indication of the percentage of the solution and the particles introduced into the body.

To reduce the amount of medicine used at high concentrations /104
of solution, it is recommended that only the sheet of filter paper placed below the cloth be moistened with the solution and not the entire cloth, which is moistened with water only.

For special purposes, e.g., in ophthalmology, hollow electrodes are also used; these consist of a vessel of some shape containing an angular stem. The vessel is filled with a solution of the proper electrolyte, after which a current is allowed to pass from the angular stem to the surface of the skin or the membrane to which the electrode is applied.

In the electrophoresis of penicillin and streptomycin, it is necessary to ensure that the products of electrolysis formed on the electrodes do not reduce its activity. For this purpose, hollow electrodes containing a buffer solution are used, or else multiple layers of cloth moistened with buffer solution are applied to the skin. The latter method is carried out as follows: a piece of

TABLE 12

Ion or Particle Introduced Into the Organism	Substance Employed	Percentage of Solution
I. Particles Introduced From The Positive Electrode		
Adrenalin	Adrenaline hydrochloride	0.1
Aconitine	Aconitine nitrate	0.001-0.002
Vitamin B_1	Aqueous solution	2-5
Histamine	Aqueous solution	0.01
Dionine	Dionine hydrochloride	0.1
Calcium	Calcium chloride	1-10
Codeine	Codeine phosphate	0.1
Lithium	Lithium carbonate	1-10
Magnesium	Magnesium sulphate	1-10
Novocain	Aqueous solution	1-10
Streptomycin	Streptomycin sulphate (in physiological solution)	*
Quinine	Quinine hydrochloride	1
Zinc	Zinc sulphate	0.2-2
II. Particles Introduced From The Negative Electrode		
Bromine	Sodium bromide	1-10
Iodine	Sodium and calcium iodide	1-10
Caffein	Sodium-benzoate salt of caffein in 5% sodium solution	0.1
Penicillin	Sodium salt of penicillin in physiological solution	*
Salicylate	Sodium salicylate	1-10
Sulfanilamide	Sulfanilamide in 1% sodium solution	0.8
Sulfate	Magnesium sulfate	1-10
Thiosulfite	Sodium hyposulfite	2-2.5
Phosphate	Sodium phosphate	1-3

* This streptomycin and penicillin are usually given at the rate of 500-1000 active units per 1 cm^2 of cloth and 5000-10,000 active units per 1 ml of solution.

filter paper (one layer) or gauze (two or three layers) is applied to the skin of the patient. This layer is moistened with a penicillin solution. On top of this is placed a simple piece of cloth moistened with warm water, a buffer layer made of filter paper (three layers) or gauze (four to five layers), moistened with a 5% solution of glucouse or a 1% solution of glycol, a second piece of cloth moistened with water, and on top of this the lead strip (electrode).

Ionogalvanization involves a complicated series of solutions applied to the electrode cloths and electrolytes (primarily sodium chloride) which are introduced into the tissue of the organism. In this process, the ions of the corresponding sign pass into the subjacent tissue of the organism from the solution with which the cloth is moistened, while ions of sodium or chlorine emerge from the tissue and enter the cloth.

Ions which are introduced into the organism in this manner do not penetrate to a considerable depth; they are retained in the skin and subcutaneous tissue in the region where the electrodes are applied, forming a so-called cutaneous deposit of ions, from which they later move by diffusion (gradually, over long periods of time) into the general bloodstream and are dispersed throughout the organism. In the course of this process, many of them lose their charge and are converted into atoms, whose chemical properties are different from those of ions.

The presence of a cutaneous deposit, as well as the introduction and distribution of particles introduced by electrical current into the organism has been studied recently by using the method of so-called labeled atoms. Along with the particles of some substance which are introduced into the organism, particles of its radioactive isotope are also introduced; their decay is accompanied by radiation which can easily be detected by means of a Geiger-Müller counter. By studying the intensity of this radiation in different parts of the body, we can determine both its distribution through the tissues as well as the paths followed by the substance within a living organism.

§ 2. APPARATUS FOR LOCAL GALVANIZATION AND IONOGALVANIZATION

At the present time, galvanic current for therapeutic purposes is produced almost exclusively by rectification of alternating current. There is only a very limited use of dry galvanic batteries for apparatus intended to be used under conditions where no power lines are available. Since current pulsations produce a physiological effect which is different from the effect of strictly direct currents, the amplitude of the variations in the direct current in apparatus used for producing galvanic current must not exceed 0.5%.

A special feature of rectifiers used for therapeutic apparatus is the absolute necessity of having a transformer in which

the line voltage is kept separate from the circuit which is connected to the electrode attached to the patient (it is not possible to use autotransformers or any other devices which provide a direct connection between the patient and the line voltage), and there must be absolutely no connection between any of the wires or parts of the electrical circuit to the chassis or the cabinet of the apparatus, as is usual in electronics. These requirements are related to ensuring the safety of the patient and are discussed in greater detail in the corresponding section of this book. /105

A potentiometer with a linear characteristic (usually wire-wound), connected to the output of the apparatus, is generally used to regulate the current in the wires leading to the patient. To provide sufficiently smooth adjustment during treatment, so that various current intensities can be delivered as required, the potentiometer has two sections: the beginning has a flatter characteristic than the end, which is accomplished by using wire of larger diameter in the winding.

In the period from 1950 to 1960, the Union Factory of the EMA produced the AGN-1 and AGN-2 instruments for galvanization, which

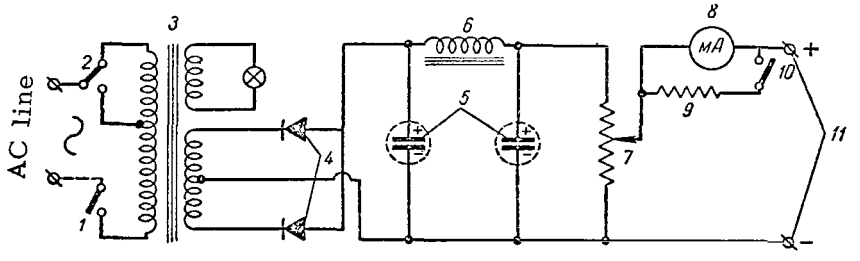


Fig. 85. Schematic Diagram of Apparatus for Galvanization, Made by the Sverdlovsk Factory.

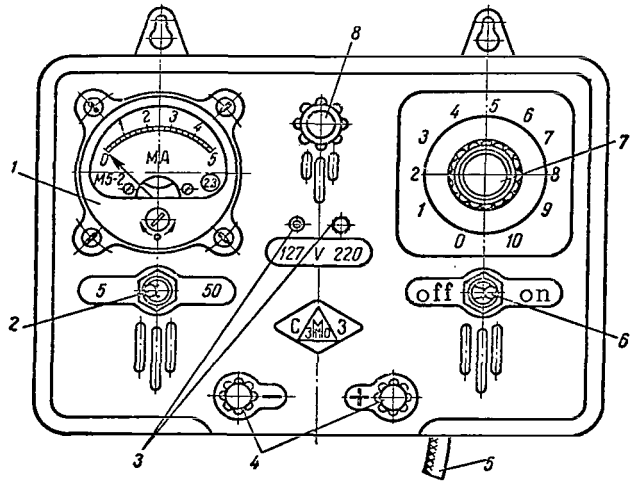


Fig. 86. Control Panel of Galvanization Apparatus.

were wall-mounted and portable (in a carrying-case),respectively; the AGVK-1 apparatus was also produced as the power supply for the four-chambered bath (see § 3). These devices are described in detail in the second edition of this book (1960).

At the present time, the Sverdlovsk Factory of the EMA is producing two types of apparatus, of which the first is called "apparatus for galvanization" and the second is called "apparatus for galvanization (high power)". The latter apparatus (with a special attach-/106 ment) can also be used for the four-chambered baths. The rectifier in the first apparatus is made of semiconductors, while the second uses vacuum tubes.

The apparatus for galvanization are produced in the following versions: (a) as a wall-mounted version (AGN-32) and (b) a portable version (AGP-33, in a carrying-case). The characteristic data of the apparatus are as follows: currents up to 50 mA are supplied, with a load resistor of 500 ohms. The potential at the output, without a load, is approximately 70 V. The power consumption is 15 W. The schematic diagram of the apparatus is shown in Figure 85. In this diagram, (1) is the line switch, (2) is the switch for selecting 127 or 220 V line voltages, (3) is the transformer, (4) are D7D diodes, (5) is a 20 μf, 150 V capacitor, (6) is a choke, (7) is a potentiometer with a resistance of 3500 ohms, (8) is a milliammeter, (9) is the milliammeter shunt, (10) is the shunt switch, and (11) are the terminals for connecting the leads to the patient.

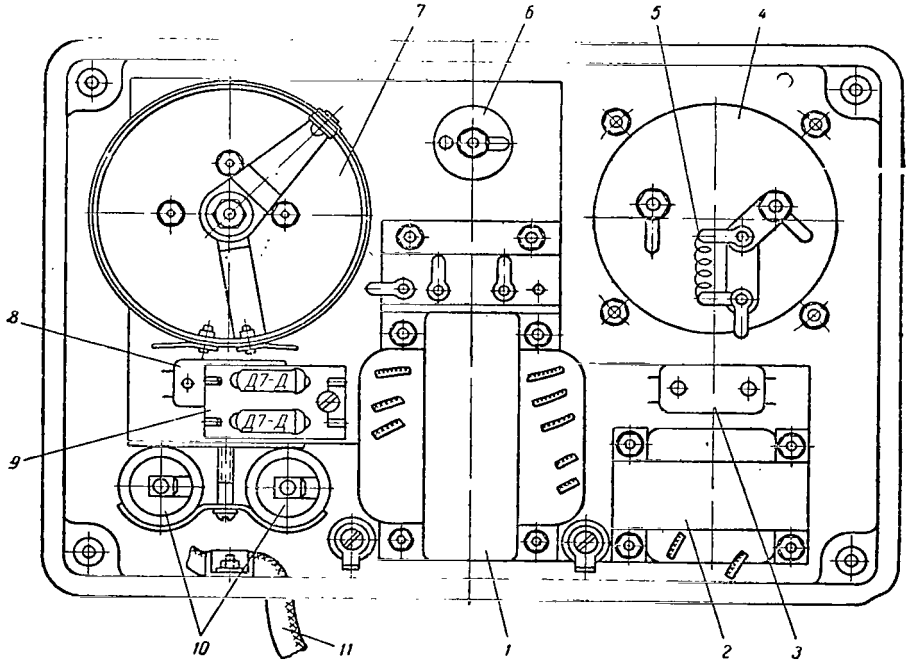


Fig. 87. Location of Parts in the Apparatus for Galvanization.

Figures 86 and 87 are schematic representations of the front panel of the apparatus, showing the location of the parts within the cabinet. The cabinet itself is made of plastic. The front panel has the following components mounted on it: milliammeter (1), shunt switch (5-50 mA) (2), line switch(6), knob for adjusting the potentiometer (7), socket (3) for selecting the line voltage, lens (8) of the pilot light, and clamp (4) for connecting the wires from the electrodes. Line cord (5) is visible at the bottom.

Inside the cabinet, transformer (1) is located in the middle. To the right and below is choke (2). Above the transformer is the line switch, and above the choke is the milliammeter shunt switch (3). In the upper right corner is milliammeter (4) with shunt (5), while at the left is potentiometer (7). The socket for pilot light (6) is located in the middle. Below the potentiometer is the diode unit (9), mounted on a support, and electrolytic capacitors (10). /107

The apparatus is supplied with wires for connecting the electrodes to the terminals (4), connecting (double) clips (2), lead for making electrodes, rubber straps (2), as well as instructions and certificate.

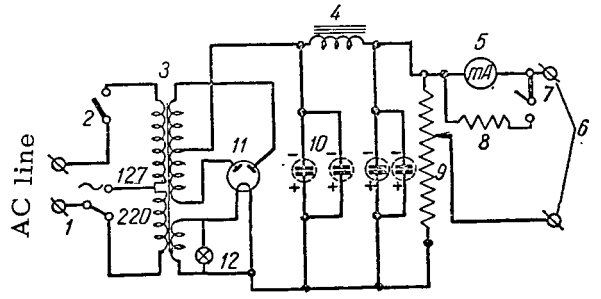


Fig. 88. Schematic Diagram of Apparatus for High-Power Galvanization.

The apparatus for high-power galvanization produces currents of up to 100 mA (with a load resistor of 500 ohms). The potential at the output without a load is about 100 V. The power consumption is 30 W.

The schematic diagram of the apparatus is shown in Figure 88. In this diagram we see (1) the switch for selecting line voltage of 127/220 V, (2) the line switch, (3) the transformer, one of whose secondary windings is intended for powering the anodes of the kenotron, while the second is used for the kenotron filaments, (4) the choke (5) milliammeter, (6) terminals for connecting leads from thepatient, (7) milliammeter shunt switch, (8) shunt, (9) potentiometer with resistance of 5000 ohms, (10) capacitor (20 μf, 150 V) (11) 5Ts4S kenotron, and (12) the pilot light socket.

Figure 89 shows a general view of the apparatus. It is contained in a plastic cabinet, on the front of which are the following: milliammeter (5), knob (6) for the shunt switch (10 and 100 mA), line switch (1), knob (4) of the potentiometer, terminals (7) for connecting the leads from the patient, socket (2) for the switch which connects the transformer windings to different line voltages, and lens (3) of the pilot light. On the side of the cabinet is /108

the line cord and plug for connecting the apparatus to the line voltage.

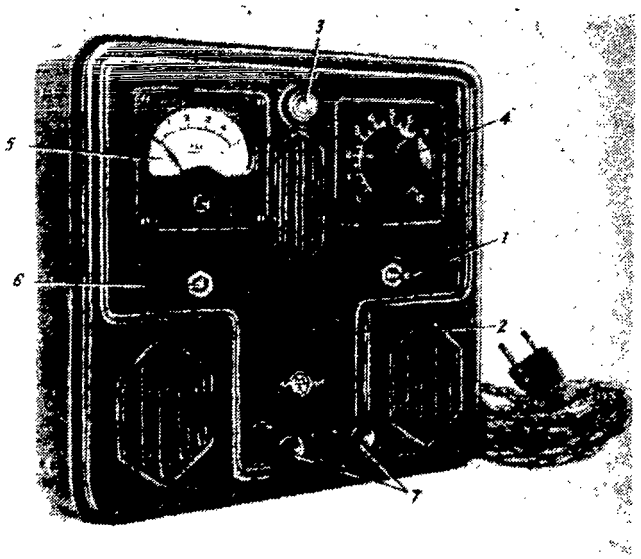


Fig. 89. General View of Apparatus for High-Power Galvanization.

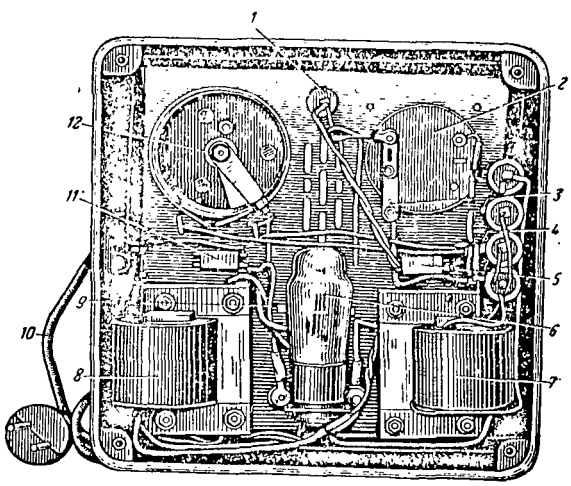


Fig. 90. Arrangement of Parts in Apparatus for High-Power Galvanization.

Within the apparatus (Fig. 90) are the following parts: at the bottom left, transformer (8), at the right, choke (7). Above the transformer is the line switch (11), and above the choke is the shunt switch (5). At the top right is milliammeter (2) with shunt (3), and potentiometer (12) is located at the left. At the top center is socket (1) for the pilot light, and below it is kenotron (6). On the right side above the choke are the electrolytic capacitors. Behind the kenotron is the switch panel (9) for the supply voltage.

The apparatus is supplied with the same equipment as the preceding; there is also a spare kenotron and pilot light.

The apparatus is used for galvanization and ionogalvanization as follows. Before plugging the apparatus into the wall, it is

necessary to check that the voltage for which the transformer is set corresponds to the available line voltage and that the line switch is set to the "off" position. The plug can then be inserted into the wall socket. It is then necessary to be sure that the potentiometer knob is set to the zero position and the milliammeter shunt switch is in a position which corresponds to the amount of current to be used for treatment. The power can then be turned on; the switch knob is then set to the "on" position, and the potentiometer knob is used to set the current required for treatment. It is important to remember that during the first two or three minutes after switching on the apparatus, the current in the electrode circuit will increase somewhat for the reasons given above, so that the current should initially be set somewhat lower than the desired value and changed to the final position only after several minutes have passed. During the treatment, the current setting should be checked periodically and adjusted if it varies from the desired setting.

In regulating the current with the potentiometer, it is necessary to watch the deflection of the milliammeter needle carefully. /109
Turn the knob of the potentiometer very slowly and evenly when increasing or decreasing the current. Otherwise the patient will feel unpleasant sensations.

In giving the treatment, it is necessary to observe the safety rules so that the patient will not be grounded. More detail will be given in this respect in the section called "Safety Precautions".

§ 3. APPARATUS FOR GENERAL GALVANIZATION, WITH BATHS FOR THE EXTREMITIES

In addition to the local treatment method, there is also the method of "general galvanization", in which flexible electrodes are attached to both forearms and to both shins and connected to a single terminal on the apparatus by means of the double connecting clips, while the inactive electrode (which is much larger, about 600-800 cm^2) is attached to the waist and connected to the second terminal of the apparatus.

General galvanization is frequently administered by means of special electrodes for the extremities which take the form of earthenware baths. Shallow vessels are used for the upper extremities, with the patient bending his arm at the elbow and submerging it in the water so that the elbow joint is covered. Deeper vessels are used for the lower extremities, in which the legs are submerged up to the knee. Treatment is performed with the patient in the sitting position. Each of the baths is fitted with a holder containing graphite electrodes (two for each bath). These electrodes are connected to the apparatus by connecting clips.

The baths are filled with warm water (temperature of 35-37°, according to the doctor's instructions). Ionogalvanization is also

performed with medicinal liquids in the baths. The same solutions are used as for local galvanization, with the same or somewhat

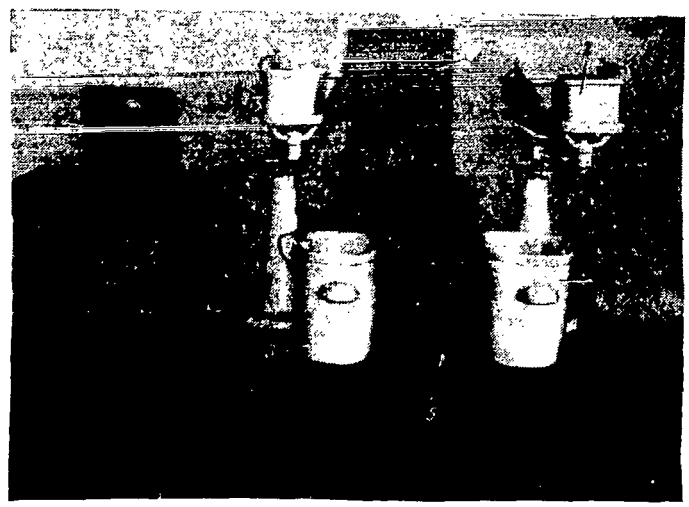


Fig. 91. General View of Apparatus for General Galvanization, Using Baths for the Extremities.

weaker concentrations. The introduction of ions into the organism by means of these baths, filled with hot water, is more effective than when electrodes and cloths are used. The hot baths themselves also have an important role in the general curative effect when applied to the extremities. In this regard, such a method is sometimes referred to as a hydrogalvanic bath (the old name for the treatment is "four-chambered hydrogalvanic bath"). /110

Figure 91 shows a general view of the apparatus for general galvanization, with baths for the extremities. The apparatus consists of a common wooden platform (5), on which is mounted a chair (4) for the patient and four baths: two for the legs (3) and two for the arms (2), mounted on special holders. Beside the chair (usually suspended on the wall) is the power supply (1).

The power supply for the four-chambered bath, as we have mentioned, was formerly manufactured as a separate unit with the designation AGVK-1. The AGVK-1 apparatus was used for high-power galvanization, and was equipped with four switches and six output terminals for independent connection of the electrodes in each bath, and any desired polarity could be applied to the apparatus (see second edition of this book, 1960).

At the present time, the "apparatus for high-power galvanization" described above is used for this purpose. To make it easy to connect the electrodes from the baths, the factory supplies a

special attachment for the apparatus, fitted with terminals and switches [Fig. 92, where (1) is the apparatus for galvanization and (2) is the attachment].

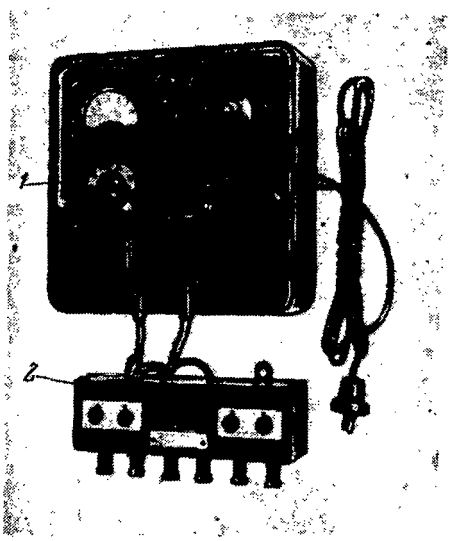


Fig. 92. Apparatus for Galvanization, With Attachment for Powering the Electrides in the Baths for Extremities.

The method must be carried out with a wooden chair having the back sloped somewhat for the comfort of the patient's back. The treatment is carried out as follows. The baths are filled with water or medicinal solution according to the doctor's instructions. A thermometer is used to check the temperature of the liquid. Graphite electrodes are placed in the holders on the baths, and connected by wires to the terminals on the apparatus which have the proper polarity (either directly or through connecting clips). If the special apparatus or the attachment is being used, the polarity switches must be set to the required position. The knob of the milliammeter shunt switch is set to the position corresponding to the current intensity required for treatment.

The patient sits down in the chair and places first his legs and then his arms in the baths. The positions of the latter are then adjusted so that the patient is comfortable. The patient lowers his extremities into the baths and the water level is then adjusted as necessary.

After checking that the knob of the adjusting potentiometer /111
is at the far left (zero) position, the apparatus is plugged into the wall and the potentiometer knob is turned slowly, gradually, and evenly, thus setting the desired current intensity, while checking to be sure that the current does not produce any painful sensations. When the desired time for treatment has elapsed, the knob of the potentiometer is slowly turned in the opposite direction, thus smoothly and gradually reducing the current to zero; the apparatus is then unplugged from the wall. The patient removes his extremities from the baths and dries them with a towel.

The water is then emptied from the baths and they are washed with hot water and disinfectant solution.

Special attention should be given in setting up the apparatus for the four-chambered bath to the methods of adding and re-

moving water. The baths are filled from an ordinary faucet, with both hot and cold water being supplied. To protect the patient from possible grounding, the water faucets must be located 1-1.5 m away from the apparatus. Rubber hoses are fitted to the faucets, and must be of sufficient length to allow the baths to be filled with water of the required temperature. It is absolutely necessary to avoid using any metal water pipes to connect the water supplied to the apparatus, and there should be no metal faucets located immediately above the baths.

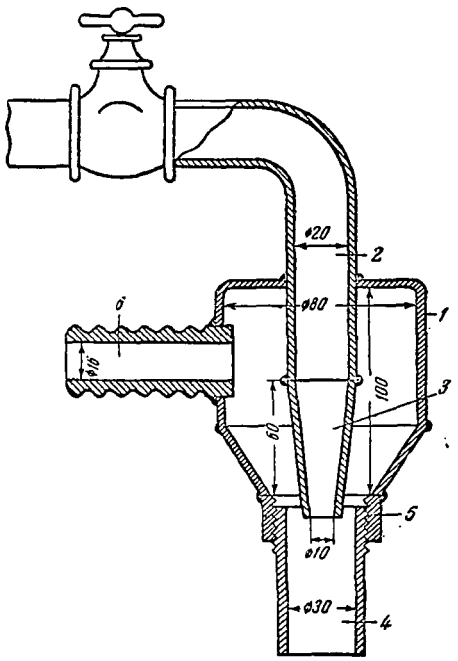


Fig. 93. Diagram of the Construction of the Aspirator.

The best way of emptying the water from the baths after treatment is to use an aspirator pump, which uses the water from the wall faucet to empty the baths. A rubber hose is connected to the aspirator and the water flows out of the baths through this hose. The aspirator can be made in any machine shop where welding is done.

The operating principle of the aspirator pump is the following. Water flowing out of a narrow opening at high speed creates a pressure drop around the opening. This reduced pressure or vacuum is used as the activating force of the pump. In the cross sectional view of the pump (Fig. 93), we see a cylindrical housing (1) with a funnel shaped area at the bottom. Tube (2) runs through the upper part of the pump and is connected to the shut-off valve on the wall faucet. Tube (2) ends in a narrow conical tip (3), whose lower end is located within a wider outlet nozzle (4). The nozzle is fitted into a cylindrical collar (5) welded to the lower end of the housing (1).

Since nozzle (4) is fitted with screw threads, it can be screwed in or out of the housing to change the amount of vacuum around the outlet of the conical tip (3). A nipple (6) is fastened to the side of the housing (1), on the end of which is a rubber hose for drawing the water out of the baths. The principal dimensions of /112 the pump are indicated in Figure 93. The inlet tube is 3/4 of an inch in diameter while the outlet tube is 1 inch in diameter. The body of the pump is made of sheet steel, 2 mm thick. The extent to which the adjustable section is screwed in or out is adjusted when the pump is installed and depends to a certain extent on the head of water in the line.

To operate the aspirator pump it is necessary merely to open the valve on the wall faucet. As the water flows through the pump it emerges from the narrow end of section (3), thus creating a vacuum inside the housing (1), so that the water is drawn out of the baths through nipple (6) into the pump housing and then flows out with the rest of the water through the outlet (4). The pump can either be connected to a drain by means of a rubber hose or it can be mounted on the wall so that the water from it runs into a sink.

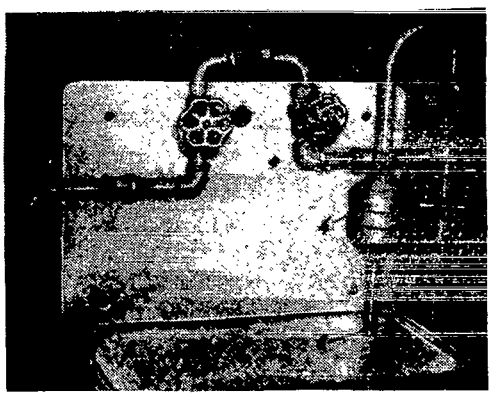


Fig. 94. Apparatus for Draining Water With an Aspirator.

Figure 94 shows an example of an installation for filling and emptying baths, using the wall faucet and aspirator pump. In Figure 94, (1) is the hot water pipe, (2) is the cold water pipe, (3) is a nipple for connecting the drainage tube, (4) is the aspirator, (5) is the suction tube, (6) is the outlet, (7) is the nipple for attaching the suction tube, and (8) is the sink for receiving the water.

An earthenware vessel without any holes can be placed beneath the outlet to catch the water.

A simpler arrangement for draining the water consists of a pan made of cement or galvanized iron placed beneath the wooden platform, and connected to a drain. The water is drained from the baths by opening valves in their bottoms, thus allowing the water to flow out through rubber tubes connected to them. The water from the arm baths runs into the foot baths (after the latter have been emptied), while the water from the foot baths runs into the pan. In an apparatus of this kind for removing the water, special safety precautions must be taken (see Chapter VI, Section 2).

PART 3

APPARATUS FOR DIAGNOSIS AND THERAPY, USING PULSED CURRENT

§ 1. ELECTRODIAGNOSTICS AND ELECTRICAL STIMULATION

Direct current, which is constant in direction and does not vary in value, produces certain physical and chemical changes in tissues which are due mainly to changes in the ion concentrations in tissue elements. These processes also constitute the therapeutic action of such currents. However, there are a number of phenomena or reactions on the part of the organism which occur only during the period of change, i.e., increase or decrease, of the current

intensity. For example, repeated application and removal of direct current causes stimulation of elements of the nervous system, which can be seen most clearly in the effects on the peripheral nervous and muscular apparatus which takes the form of contractions of the corresponding muscles. Therefore, one of the most widely employed means of stimulating the nervous system used in electrotherapy is the action of shocks or pulses of direct current. The simplest form of this kind of current is the rhythmic interruption of a galvanic current (suggested by Leduc in his time), the impulses of which have a rectangular shape (so-called Leduc current). /113

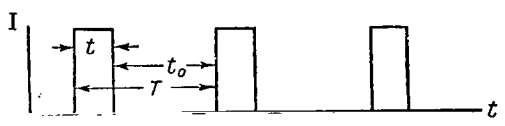


Fig. 95. Ratio Between the Pulse Duration and Period in Pulsed Current.

The principal characteristics of pulsed current (determining its physiological effect to a considerable degree) are the following: (a) the repetition frequency of the pulses, or the period of the pulsed current; (b) the duration of each pulse, or the so-called spacing of the current, equal to the ratio of the period to the pulsed duration; (c) the shape of the pulse, especially the steepness of the leading front.

Figure 95 shows a graph of pulsed current with rectangular shape. If we call the repetition frequency of the pulses f Hz, then the period of pulsed current will be $T = 1/f$ sec. If the pulse duration is then set to t sec, the pause after each impulse will be $t_0 = T-t$ sec and the spacing will be $S = T/t$.

The spacing (with a rectangular pulse) also involves a ratio between the average and amplitude values of the voltage U or current I;

The average value of the voltage $U_{av} = \frac{U_a t}{T} = \frac{T_a}{S}$.

The average current is $I_{av} = \frac{I_a t}{T} = \frac{I_a}{S}$, where U_a and I_a are the amplitude values of the voltage and current. Conversely, $U_a = SU_{av}$ and $I_a = SI_{av}$.

Thus, the average value of the pulsed voltage or current is equal to the amplitude value divided by the spacing. On the other hand, the amplitude value of the voltage or current is equal to the average multiplied by the spacing.

It is important to recall in this regard that the stimulating effect of pulsed current depends primarily on the amplitude value of the current and the pulse duration. The average value of the current in this respect is much less characteristic. At the same time, however, the average value of the current can be measured by magnetoelectric devices which are in widespread use;

the measurement of the amplitude value for very brief pulses requires special measurement devices.

Modern electronic technology has made it possible to produce current pulses whose parameters vary within very wide limits, which can be measured (e.g.) in units of frequency up to millions of hertz, with durations all the way from seconds to microseconds. The pulses/114 can also be changed in form over wide limits, and practically any type of pulse that can be recorded on paper can be produced.

Figure 96 shows the graphs of the different types of pulsed current which are in general use in medicine:

(a) Faradic current in its classical form, or current from an induction coil;

(b) Tetanizing current, consisting of brief triangular pulses, producing separate pulses of faradic current;

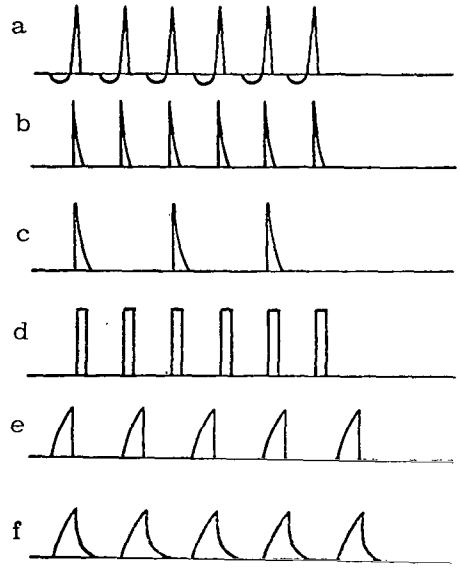


Fig. 96. Pulsed Currents of Different Types.

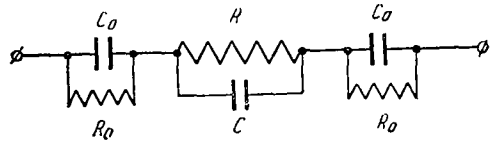


Fig. 97. Equivalent Electrical Circuit for the Tissures of an Organism.

(c) Capacitor discharges with an exponentially decreasing trailing edge;

(d) Rectangular pulses;

(e) Exponentially increasing pulses;

(f) Exponentially increasing and decreasing pulses.

In using pulsed current for stimulating the tissue of an organism, it is necessary to keep in mind that the electrical conductivity of tissues is not purely ohmic, but also has a capacitance component. In its most general form, the equivalent electrical circuit representing the conditions existing between the electrodes when a constant or pulsed current is applied, can be constructed in the form of several resistors connected in series, each of which is shunted by a capacitor (Fig. 97). In this diagram, R_0 and C_0 represent the resistance and capacitance of the electrodes, the cloth, and the layer of skin and subjacent cells; the capacitance elements

have a relatively high value, while R and C are the resistance and capacitance of tissues located deeper within the organism, in which the capacitance has a lower value.

In a first approximation for pulsed current of rectangular shape, at the small current levels used in practice, the following values can be assumed for the components in this circuit: R_0 = 1,000, 2000 Ω, C_0 = 0.3=0.05 μf, R = 500-1;000 Ω, and C = 0.01-0.02 μf.

As a consequence of the capacitance properties of tissue, the shapes of the current pulses passing through them differ somewhat from the shapes of the pulses of the applied potential. This fact must be taken into account in accurate studies. It is not of great importance in conventional medical or diagnostic practice. For the sake of an example, Figure 98 shows the schematic representation of current pulses *I* which are obtained when rectangular voltage pulses are acting on the tissue of an organism.

The determination of the functional or anatomical state of nerve/115 pathways or muscles by stimulating them with an electrical current is called electrodiagnostics. This method involves comparison of the shape of an electrical stimulus with the nature of the response reaction evoked (in the form of a muscle contraction).

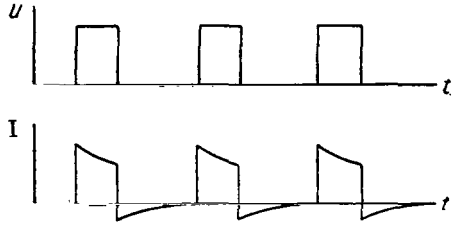


Fig. 98.

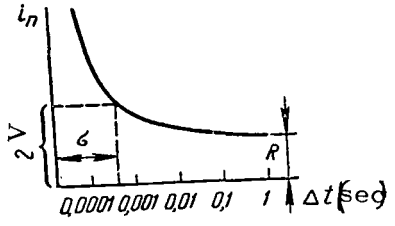


Fig. 99.

Fig. 98. Shape of Voltage and Current Pulses Passing Through the Tissue of an Organism.

Fig. 99. Curve of Electrical Stimulatability of Muscle.

Depending on the nature of the electrical stimulus, methods of electrodiagnostics can take different forms. The simplest of these is the so-called classical method, in which the nature of the contractions of the stimulated muscles is compared for stimulation with constant and tetanizing currents (Fig. 98, b). Regardless of the existence of much more complete methods, the "classical method" has retained its importance as the simples, fastest and least complicated method, and is also a highly reliable method of electrodiagnostics.

The most widely employed and complete method is that of elec-

trodiagnostics employing single rectangular pulses (Fig. 98, d). The method is based on the fact that the stimulating action of brief pulses of current (small fractions of a second) depends on their duration. This dependence is expressed by the so-called electrostimulatability curve, which shows the relationship between the current intensity i_n, which produces the threshold (i.e., minimum significant) reaction to stimulation, and the duration Δt of a single current pulse. This curve is also called the "intensity-duration" curve. An example of such a curve is shown in Figure 99.

The method of chronaximetry is also based on the relationship between the stimulating effect of individual current pulses and their duration. In this method, the two characteristic parameters of the curve of electrostimulatability are determined. The first of these is the rheobase R (Fig. 99), which is the current intensity required for threshold stimulation regardless of the pulse duration. The second is called the chronaxis σ and is the pulse duration corresponding to threshold stimulation, equal to twice the rheobase. Chronaximetry is a much simpler method of investigation than determination of the intensity-duration curve, and was formerly conducted with the use of capacitor discharges. The modern apparatus for this purpose is called the "capacitor chronaximeter".

In addition to stimulation by individual pulses, electrodiagnostics also employs stimulation by pulses which are repeated at a certain frequency ("frequency" stimulus). This involves determination of a certain value called the "lability" which characterizes the ability of a tissue or organ to respond to a given stimulation rhythm. Investigation has revealed the relationship between the nature of the muscle contractions and the frequency of the electrical stimulus. Electrodiagnostics is performed by means of rectangular pulses whose frequency changes within very wide limits.

There are other methods of electrodiagnostics in which the /116
relationship between the nature of the muscle contraction and the shape of the current pulse is determined, especially the slope of the leading edge. Triangular or exponential pulses are used in this method (Fig. 96, e).

Finally, there are still more complex methods of studying electrostimulatability, in which all three basic parameters of electrical pulses are varied either simultaneously or in certain combinations: duration, frequency, and shape.

Electrical stimulation of nerve pathways and muscle is used in the same way as the method of treating nervous and muscular problems, and employs artificially induced contractions to maintain muscle activity when the innervation of the latter is disturbed. This method is called electrostimulation (the old name is electrogymnastics). Electrostimulation uses the same devices for electrical stimulation as are used for electrodiagnostics. Electrodiagnostics is usually performed first, in order to determine the

functional state of the nervous and muscular apparatus as well as to determine the most favorable parameters for the electrical stimulation to be used. Therefore, muscle stimulation can be carried out with current which has parameters which have been established in this way.

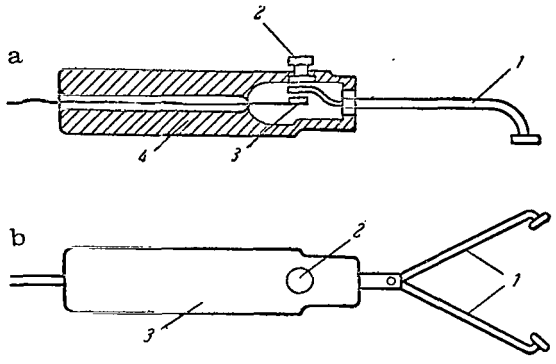


Fig. 100. Electrodes for Electrodiagnostics. (a) Unipolar; (b) Bipolar.

In both electrodiagnostics and electrostimulation, the electrical stimulus is transmitted to the object by means of two electrodes: an active one and an inactive one. The active electrode has a small area (less than 1 cm^2) and is therefore called a point electrode. The inactive electrode has the shape of a large strip. Such a method of stimulus is called unipolar. An electrode of this kind (Fig. 100, a) is shaped like a bent rod (1) with a flattened tip, (4). The handle is equipped with a pushbotton switch (2-3) which permits the investigator to turn the current on and off. The end of the electrode is covered with cloth, which is moistened with warm physiological solution or water during the examination. The inactive electrode is also covered with a moist cloth.

In electrostimulation by the unipolar method, one can use either a similar type of point electrode (but without a switch), or a small lead strip covered with cloth can be placed on the point to be stimulated and held in place with a rubber strap.

In electrodiagnostics, and especially in electrostimulation, it is common practice to use a bipolar method of stimulation. The electrode used in electrodiagnostics of this variety is shown in Figure 100, b and consists of two bent rods (branches) (1) with flat tips (like the unipolar electrode), mounted in a common handle (3). The branches of the electrodes are adjustable and can be set to any desired distance. Leads from the apparatus run to both branches. The handle of the electrode is fitted with a swith (2), connected to the circuit of one lead.

In bipolar stimulation, both electrodes are active and are /117
active and are applied to two points: either at the ends of the muscle to be investigated or along a portion of a nerve pathway. In bipolar electrostimulation, two small cloth-covered lead strips are used, which are placed on the ends of the muscle to be stimulated (or the group of muscles), and held in place with a elastic strap.

In electrostimulation of muscles, electrical stimulus must be applied to the muscle rhythmically, with pauses between pulses, since the muscle must be allowed to rest between contractions. This requires apparatus for electrostimulation of muscles which can supply rhythmic pulses of current to the electrodes on the patient.

In cases when the patient still has the ability to make even slight active motions with his damaged muscles, so-called active stimulation is used. Active stimulation consists of the following: electrical stimulus is combined with the attempt of the patient to make an active movement. The electrical stimulus serves as a means of increasing the muscle contraction and thus restores more completely the disturbed function. The pulsed current is then administered in separate pulses by means of a special control operated by the foot or hand.

Another method of using pulsed currents of different types for medicinal purposes is the so-called diadynamic therapy, developed by Bernard. In this method, pulsed current of some variable sinusoidal shape (see Fig. 122), modulated in the form of pulses of different duration, is employed. This current is conducted to the part of the body which is being treated by means of electrodes similar to those used in galvanization. Diadynamic currents are used for getting rid of pains and trophic disturbances in tissues.

§ 2. VACUUM-TUBE APPARATUS FOR PRODUCING PULSED CURRENT

The principal method of obtaining pulsed current in the apparatus described below is the multivibrator. Other devices used are the blocking generator, thyratrons operating on alternating current with a cutoff, and one or two half-cycle rectifiers (Bernard currents).

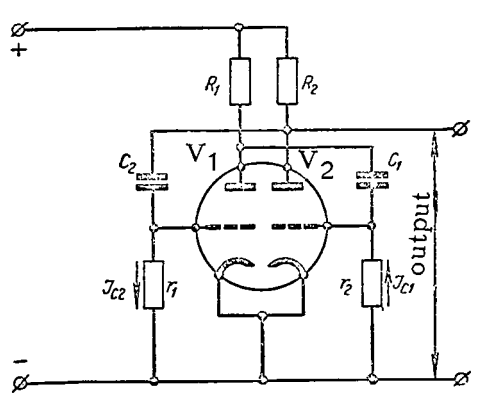


Fig. 101. Schematic Diagram of a Multivibrator with Self-Excitation.

A multivibrator consists of two triodes, whose anodes and grids are connected by capacitors and resistors.

Let us examine the operating principle of a very simple multivibrator with self-excitation (Fig. 101). When the supply voltage is applied to the multivibrator, a certain amount of current passes through each tube and voltages appear on the anodes of the tubes, causing capacitors C_1 and C_2 to be charged to a certain voltage. However, due to random variations of the current in the tubes, this balanced state is unavoidably disturbed. Let

us assume that the anode current on the grids of tube V_1 increases somewhat. This increases the voltage drop across resistor R_1 and a corresponding decrease in the voltage on the anode of the same tube V_1. This means that capacitor C_1 begins to discharge through /118 tube V_1 and resistor r_2. The discharge current of capacitor C_1, passing through resistor r_2, as shown by the arrow, produces a negative potential on the grid of tube V_2. This causes a drop in the current through tube V_2 and a corresponding decrease in the voltage drop across resistor R_2 as well as an increase in the anode voltage of tube V_2. Capacitor C_2 then charges, and the charge current passes through resistor r_1 (as shown by the arrow), thus forming a positive potential on the grid of tube V_1, increasing the current through the tube still further, etc.

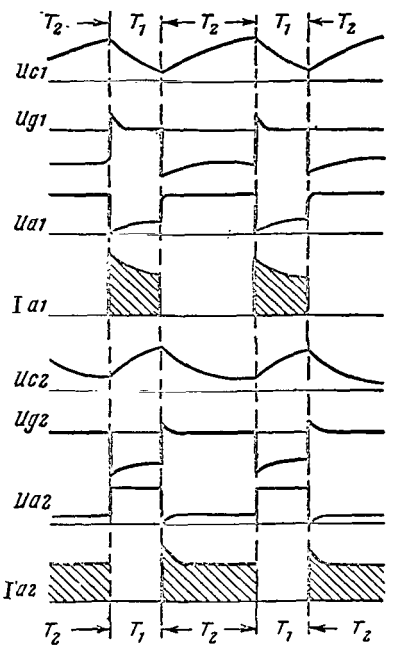


Fig. 102. Graph of Operation of a Multivibrator With Self-Excitation.

As a result of these processes, the anode current of the first tube increases to the maximum value permitted by the tube characteristic, while tube V_2 is blocked: its current I_{a_2} drops to zero. This means that between the triodes in the multivibrator, there is a strong positive feedback, and the rapid rise and fall of the current in them is of avalanche type. This is how the self-excitation of the multivibrator takes place.

The stable condition which exists when one of the tubes of the multivibrator is completely open and there is a positive potential u_{g_1} on its grid, while the second tube is closed and there is a negative potential u_{g_2} on its grid, lasting for a certain period of time T_1 (see the graph in Fig. 102). During this time, capacitor C_1 charges and the potential across it u_{c_1} drops; capacitor C_2, on the other hand, charges and the potential across it (u_{c_2}) increases. When the discharge current of capacitor C_1, expressed by an exponential curve, drops to the point where the voltage drop across resistor r_2 becomes smaller than the cutoff potential of tube V_2, the tube opens.

When current flows through tube V_2, its anode voltage drops owing to the reduction of the voltage across resistor R_2. This causes capacitor C_2 to discharge and a negative potential to appear on the grid of tube V_1. The current in tube V_1 drops, etc. This process is called inversion of the multivibrator. This is a period shown in the graph as T_2, during which capacitor C_1 charges and the

potential at its terminals (u_{c_1}) increases, capacitor C_2 discharges and the voltage across it(u_{c_2}) drops. The anode current in the first tube I_{a_1} drops to zero, while the anode current in the second tube I_{a_2} reaches a maximum.

As we can see from the graph, period T_1 corresponds to the current pulse in the circuit of tube V_1 and the pause in the circuit of tube V_2, while the period T_2 corresponds to a pause in the circuit of tube V_1 and a current pulse in the circuit of tube V_2.

The frequency of the pulses, as well as the relationship between the pulse duration and the pause in each tube, is determined on the one hand by the ratio between the time constants of the grid circuits ($C_1.r_2$ and $C_2.r_1$, and on the other hand by the ratio be- /119
tween the actual values of these capacitances and the resistors by whose variation they are controlled.

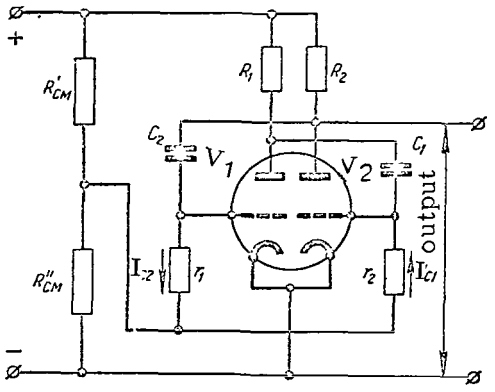


Fig. 103.

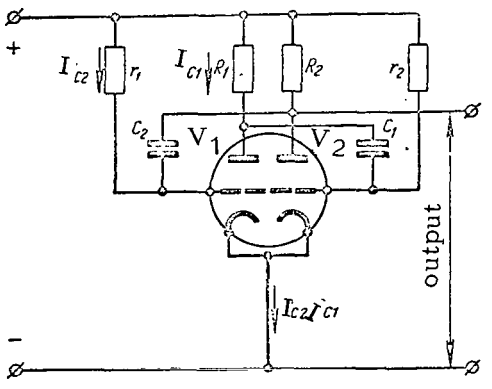


Fig. 104.

Fig. 103. Schematic Diagram of Multivibrator With Positive Bias on the Grids.

Fig. 104. Schematic Diagram of Multivibrator With Grid Resistors Connected to the Positive Pole of the Power Supply.

A load is usually connected parallel to one of the anode resistors or to the actual triodes of the multivibrator.

A multivibrator can be used to obtain pulsed current with very wide limits of frequency variation: from one pulse every few seconds to hundreds of thousands of pulses per second. The shape of the pulses is nearly rectangular. To accelerate the blocking process, as well as to stabilize the blocking frequency, which depends on the stability of the potential which blocks the triodes of the multivibrator, the so-called multivibrator with positive grid is used. In this type of circuit, a positive bias from the voltage divider

is applied to the grids of the triodes (see the circuit in Fig. 103), or the grid resistors are connected to the positive pole of the power supply (see Fig. 104).

The operation of a multivibrator with positive grids (as shown in Fig. 104) can be explained as follows. Let us say that at a certain moment in time triode V_1 is blocked while triode V_2 is open. The voltage on the anode of V_1 is high and capacitor C_1 is charged through resistor R_1 and a portion of the circuit consisting of the grid and cathode of triode V_2. The resistance of the latter is small so that capacitor C_1 is charged quite rapidly. When capacitor C_1 is charging, the voltage on the grid of triode V_2 becomes zero. During this time, capacitor C_2, which was charged during a previous period when triode V_2 was blocked, discharges through resistor r_1, the anode circuit of triode V_2 and the resistance of the power supply. The voltage drop produced by this current across resistor r_1 at the beginning of discharge exceeds the voltage of the power source, so that the grid of triode V_1 shows a negative potential (with respect to the cathode), which forces the triode into a blocked state. When the discharge current from capacitor C_2 and the corresponding voltage drop across resistor r_1 decreases to the point where the negative potential formed by them on the grid becomes smaller than the blocking potential, triode V_1 opens and capacitor C_1 begins to discharge through triode V_1 and resistor r_2. The voltage drop across resistor r_2 forms a negative potential on the grid of triode V_2, and the latter closes. Hence, the tubes have changed places, i.e., the multivibrator has reversed itself. /120

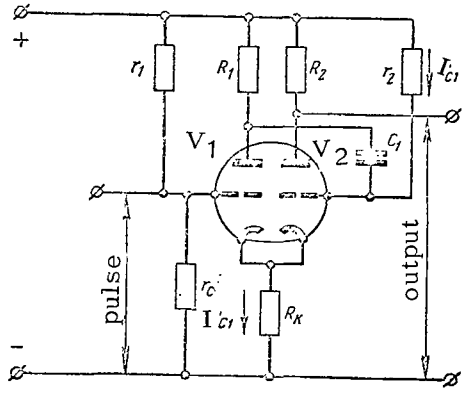


Fig. 105.

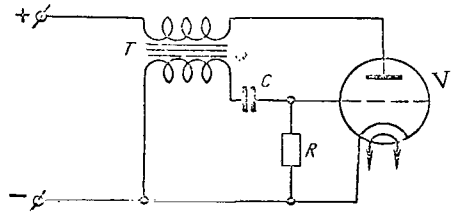


Fig. 106.

Fig. 105. Schematic Diagram of Multivibrator With Independent Excitation.

Fig. 106. Schematic Diagram of Blocking Generator.

The frequency and duration of the pulses is controlled by changing the values of the capacitors and resistors in the arms of the multivibrator, as well as by changing the value of the positive

potential on the grids according to the circuit in Figure 103 or by changing the values of the grid resistors in the circuit in Figure 104.

Figure 105 shows a multivibrator with independent excitation (also called a driven multivibrator or trigger generator). The right-hand triode V_2 is connected like a multivibrator with self-excitation. The left-hand triode V_1 does not have a capacitor in its grid circuit; brief pulses can be applied to this grid to trigger the multivibrator. Resistor R_1 is much greater than resistor R_2. Therefore the current through the triode V_2 is much greater than the current through triode V_1. A bias resistor R_k is connected in the common circuit to the cathodes of triodes V_2 and V_1.

Triode V_2 is normally open, while triode V_1 is closed by a negative bias on resistor R_k, producing a high current in triode V_2. Capacitor C_1 charges. When a positive pulse of voltage is sent to the grid of triode V_1, the latter opens and the voltage on its anode drops. Capacitor C_1 discharges (through triode V_1), the discharge current passes through resistor r_2 and produces a significant voltage drop across it, so that the grid potential becomes negative and triode V_2 closes. This continues until capacitor C_1 discharges (with a time constant on the order of $C_1 . r_2$). When capacitor C_1 is discharging, triode V_2 opens and the current (much greater in value than the current in the first triode) forms a very high negative bias across resistor R_k, which closes triode V_1. The multivibrator returns to its original state until a new triggering pulse arrives.

The blocking generator (Fig. 106) consists of a three-element tube, whose anode and grid circuits are connected by a transformer T with a low transformation coefficient and minimum loss, i.e., a maximum inductive link between the windings. The ends of the secondary are connected so that when the anode current increases, a potential will appear on the grid which is positive relative to the cathode; when the current decreases, this potential will be negative. Capacitor C and leak resistor R are connected in the grid circuit.

When the supply voltage is connected to the anode circuit, /121
a current is produced. This generates an e.m.f. in the secondary winding of the transformer, consisting of the positive potential u_g on the grid of the tube. This causes anode current I_a to increase rapidly to the maximum value permitted by the tube characteristic. At the same time, a considerable current appears in the grid circuit and capacitor C begins to charge.

Current I_a causes a considerable voltage drop across the anode winding of the transformer and voltage U_a at the anode of the tube decreases. However, owing to the high positive potential on the grid, the drop in anode potential has almost no effect on the value

of anode current I_a and the latter retains a nearly constant value for a certain period of time. In the graph representing the operation of the generator (Fig. 107), this period is represented by T_1 and corresponds to a current pulse in the tube circuit.

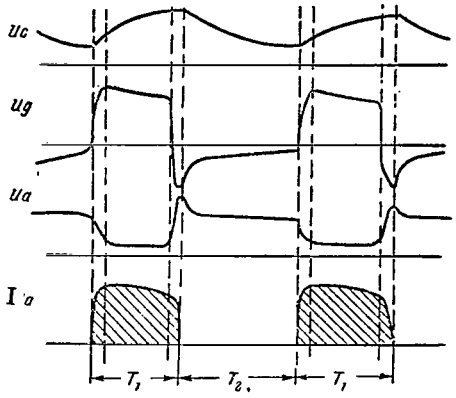


Fig. 107.

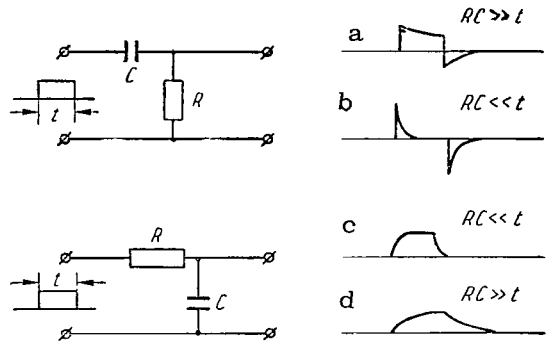


Fig. 108.

Fig. 107. Graph of Operation of Blocking Generator.

Fig. 108. Schematic Diagram of Shaping Circuit. a and b, Differentiating; c and d, Integrating.

Capacitor C continues to charge and the potential u_c across it increases. As the potential at the capacitor terminals increases, the grid potential relative to the cathode, which is equal to the difference between the e.m.f. u_g produced in the secondary winding of the transformer and the potential u_c at the terminals of capacitor C, begins to decrease. This produces a corresponding decrease in the anode current. The e.m.f. in the secondary winding of the transformer then changes sign and the grid potential as well as the anode current rapidly drop to zero (avalanche) and the tube is blocked by the negative potential of capacitor C. A pause occurs between the pulses.

The capacitor then begins to discharge through the leak resistor and the voltage across it (u_c) as well as the negative potential u_g of the grid decrease. When the negative voltage on the grid drops to a value which permits the tube to open, the process of development of an anode current is repeated. The discharge time of the capacitor up to a certain voltage controls the duration of the pauses between pulses (period T_2 in the graph in Fig. 107). Then the operating cycle of the generator is repeated.

The pulsed current from a blocking generator is obtained by connecting a load in the anode or grid circuit of the tube. It is also possible to use a transformer with three windings; the load /122 is connected to the third winding.

The pulse frequency of the current in the blocking generator

depends primarily on the time constant RC of the grid circuit, while the pulse duration depends on the capacitance of the capacitor and the parameters of the interelectrode transformer T. The blocking generator is used primarily for obtaining brief pulses (on the order of microseconds or milliseconds) with a high off-duty factor. The shape of the pulses is nearly rectangular.

In some cases the so-called shaping circuit is used to obtain pulses of the desired shape. This circuit consists of capacitors and resistors properly connected. The shaping circuit is called differentiating if it consists of a capacitor C connected in series and a resistor R connected in parallel. A circuit of this kind for a time constant exceeding the pulse duration ($RC > t$) produces the last shape shown in Figure 108, a; with a time constant much smaller than the pulse duration ($RC \ll t$), the circuit converts the rectangular pulse of constant polarity into two brief pulses of different polarity (Fig. 108, b).

The shaping circuit is called integrating if it consists of a resistor R connected in series and a capacitance C connected in parallel. Such a circuit "brakes" the pulse, giving it an exponentially rising and exponentially falling shape (Fig. 108, c and d).

§ 3. APPARATUS FOR CLASSICAL ELECTRODIAGNOSTICS

For a number of years, the Union Factory of the EMA has produced apparatus for classical electrodiagnostics with the designation KED-2. In 1955, the factory improved the apparatus, changing its electrical components somewhat and reducing its size and weight. The apparatus was renamed the KED-5. After about a year of experimental use, the apparatus was improved once again and is now being produced with the designation KED-5M.

All of these instruments use the principle of developing galvanic and tetanizing current by means of a rectifier, consisting of two thyratrons powered by a source of alternating current. When tetanizing current is being delivered, the thyratrons operate with a high cutoff, so that during each half period of the line voltage, a brief peaked pulse is formed, lasting 0.0015-0.002 sec. The pulse frequency is 100 Hz. The cutoff is obtained by means of a considerable phase shift in the voltage, fed to the grids of the thyratrons, relative to the anode potential.

When galvanic current is being delivered, a ripple filter is connected to the rectifier output.

A new feature of the KED-5 and KED-5M instruments is the use of a more sensitive measuring device, as well as an increase in the sensitivity of regulation of output voltage. The switch for selecting operational regimes has two stages for galvanic current which can be regulated from 0-5 and 0-50 mA and two stages for

tetanizing current, which can be adjusted between 0-10 and 0-50 mA.

The switch contacts not only control the shunt of the apparatus but (what is more important) connect different voltages to the output potentiometer. This means that the entire potentiometer can be used completely within each range of regulation.

The following are nominal data on the KED-5 and KED-5M instruments: /123

(a) Galvanic current: the permissible percentage of pulsations has a maximum of 0.5%, while the maximum output voltage with a load resistor of 4000 ohms is 120 V.

(b) Tetanizing current: pulse duration is 0.002 sec, with a frequency of 100 Hz; the maximum output voltage in the amplitude value of the pulse with a load resistor of 4000 ohms is 170 V.

The overall dimensions are 310 × 280 × 150 mm, and the weight of the apparatus is 8 kg. It draws 60 volt-amperes of power.

The schematic diagram of the KED-5M is shown in Figure 109 (a description of the circuit for the KED-5 will be found in the Second Edition of this book, 1960). The line voltage passes through the coupling capacitors 5 and 6 which serve for reducing radio interference, through switch S_1, fuse F, and then to the primary winding of transformer Tr. The winding is divided between a section for 127 V (terminals 1 and 2) and 220 V (terminals 1 and 3). The different sections of the winding are connected by setting the fuse to the proper position, as marked on the cover. The transformer has a filament winding (terminals 9 and 10) to which is connected pilot light L_3, the step up winding with medium current terminals (terminals 4-5-6) for powering the anode circuit of the thyratrons, and a winding for powering the bridge rectifier circuit (terminals 7-8). A screen (terminal 11) is connected between the primary windings and the others.

The step up winding provides a voltage of 2 × 280 V, corresponding to 2 × 400 V in amplitude value. The end terminals are connected to the anodes of the thyratrons, while the middle terminal is connected to the common negative lead of the entire circuit. The winding which powers the bridge circuit provides 80 V.

The bridge consists of two parts. The first is fixed and consists of a capacitor 1 and a resistor 3. The second consists of a capacitor 2 and several resistors connected in a bridge which depends on the operating regime of the apparatus. During the regime when galvanic current is being supplied, resistors 11 and 14 are connected, thus establishing a cutoff value which corresponds to a duration of anode pulses of 0.005 sec (for current between 0 and 5 mA) and 0.01 sec (for current between 0 and 50 mA). When teta-

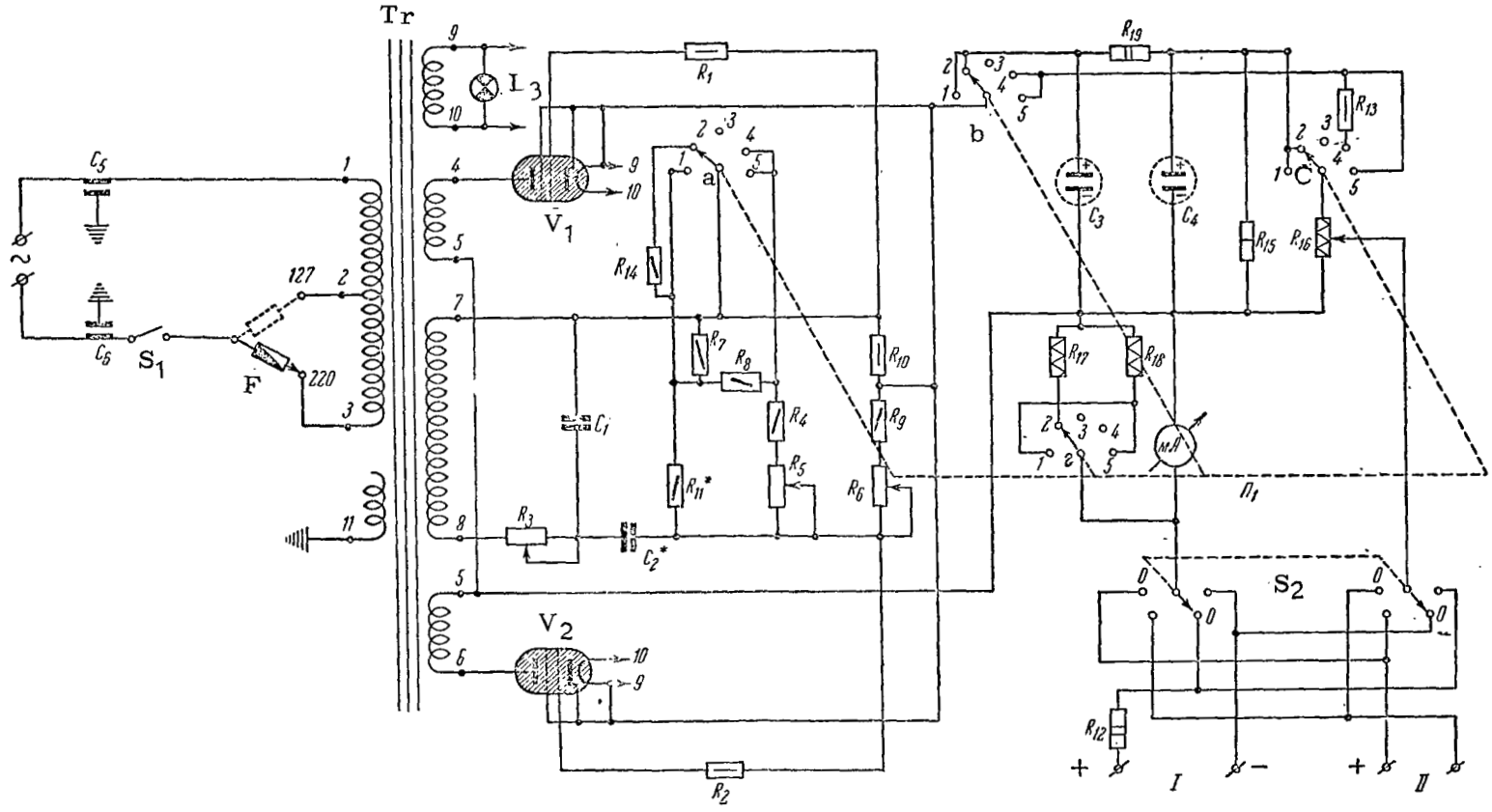


Fig. 109. Schematic Diagram of KED-5M for Classical Electrodiagnostics.

nizing current is being supplied, resistors 4 and 5 are connected to the circuit. By using variable resistor 5, the required pulse duration of 0.002 sec can be set. The voltage on the grids of the thyratrons is obtained with a voltage divider consisting of resistors 6, 9 and 10. By adjusting resistor 6, the operation of the system is made completely symmetrical, regardless of the permissible deviation in the characteristics of the thyratrons (resistor 6 must be adjusted when the tube is replaced).

Impulses of tetanizing current from the anode circuit of the thyratrons pass to the output regulating potentiometer 16, passing through a ripple filter. At small currents (0-10 mA), a resistor 13 is connected in series with the potential.

When using galvanic current, pulses on the order of 0.005 sec or 0.01 sec, respectively, are fed to the output regulating potentiometer 16 through a ripple filter consisting of resistor 19 and capacitors 3 and 4. The current pulsations are smoothed in the filter to insignificant levels.

In the KED-5M apparatus, both the tetanizing and galvanic currents are adjusted by a single potentiometer; there are two levels of adjustment for each current: 0-5 and 0-50 mA and 0-10 and 0-50 mA. Switch S_1 has five positions. Four of them are operating positions and one is a zero position in which the switch must be placed when the system is not in operation; they are designated as follows: 1 equals "gal-vanic, 5", 2 equals "galvanic, 50", 3 equals zero, 4 equals "tetanic, 10", and 5 equals "tetanic, 50". /125

The output of the apparatus has a combination switch S_2 which can be used to connect either of two pairs of output terminals to the circuit (for unipolar or bipolar studies), and also to change their polarity.

Key to Schematic Diagram

V_1 - V_2	Thyratron TG-1, 0.1/1.3
L_3	Pilot light MN-14, 6.3 V,0.28A
MA	Milliammeter M-42, 0-1 mA
F	Fuse PK-45, 0.5 A

Resistors

1-2	VS-0.5, 2.2 MΩ±10%	12	VS-2, 1 kΩ±10%
3	SP-11, 22 kΩ adjustable	13	VS-0.5, 12 kΩ±10%
4	VS-0.25, 20 kΩ±10%	14	VS-0.25, 100-200 kΩ±10%
5-6	SP-11, 22 kΩ adjustable	15	VS-1, 62 kΩ±10%
7-8	VS-0.25, 180 kΩ±10%	16	Wire-wound 10 kΩ
9	VS-0.25, 30 kΩ±10%	17	Wire-wound 4Ω
10	VS-0.5, 30 kΩ±10%	18	Wire-wound 45Ω
11	VS-0.25, 2.2-2.7 kΩ±10%	19	PE-15, 2 kΩ±10%

Capacitors

1	KBGI 400 V, 0.05 μf±10%	3-4	KE-1A, 450 V, 20±μf
2	KBG-M1 400 V, 0.15 μf±10%	5-6	KBP-S 500 V, 0.1 μf±10%

Fig. 110. General View of KED-5M.

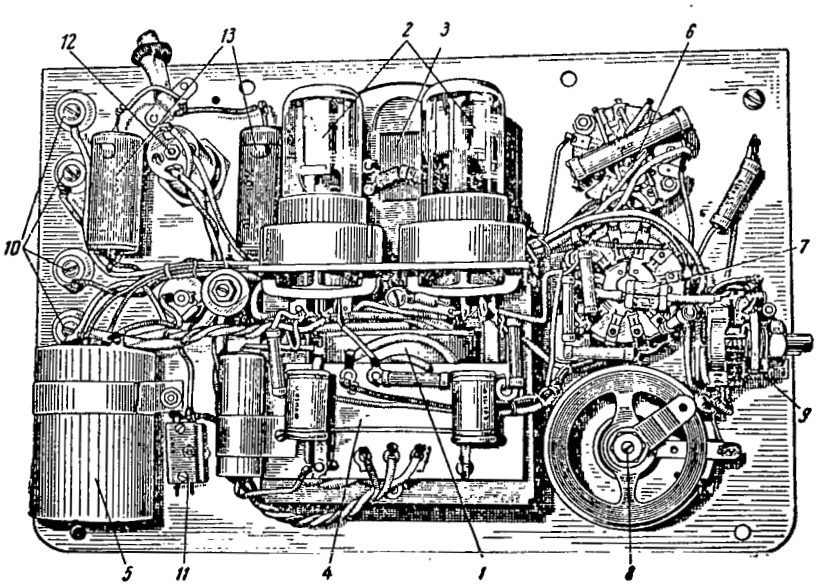


Fig. 111. Arrangement of Parts in the KED-5M.

A general view of the apparatus is shown in Figure 110. It is mounted in a metal cabinet in the shape of a small suitcase. The lower section of the cabinet contains a compartment for electrodes and attachments.

The following parts are located on the control panel: in the center is the milliammeter (1), and fuse (2) is located to the right of it. The latter is combined with the voltage-selecting switch, beneath which is lens (3) of the pilot lamp and line switch (4). On the side are the terminals (5) for connecting the appraatus to the patient, while on the left is the polarity switch (6) and terminals for connecting the patient to the apparatus. Terminal (7) is used for grounding, and is located near switch (8), for selecting the current,and regulating potentiometer (9). On the side of the panel there is a connection for the line cord.

The arrangement of the parts on the back of the panel is shown in Figure 111. At the bottom center is transformer (1), with thyratrons (2) and milliammeter (3) above it. At the left are the input capacitors (13), combination fuse and voltage selector switch (12), and line switch (11). At the lower left are filter capacitors (5), and output terminals (10) on the side. On panel (4) on the transformer, are the parts of the regulating bridge. On the right is polarity switch (6) and the terminals for attaching the apparatus to the patient, current selector switch (7), adjustable resistors (9) of the bridge, and the output regulating potentiometer (8).

The apparatus supplied with the instrument is as follows:

1. Single-pole electrode-buzzer, with lead 2 m long (1).
2. Bipolar electrode-buzzer with 1 m lead (1).
3. Waist electrode, 150 × 200 mm (1).
4. Lead for the latter, 2 m long (1).
5. Clamps for lead (1).
6. Spare thyratron (1).
7. Grounding wire (1).
8. Instruction manual, description, and certificate.

The apparatus is used as follows to perform treatment. Before /127 plugging the apparatus into the wall, it is necessary to be sure that all of the switches and knobs including that of the output potentiometer are in the zero position, and that the fuse is in a position corresponding to the line voltage (if this is not the case, it must be turned so that the arrow on the cover points to the required voltage). The "ground" terminal must be connected by a wire to a ground.

The plug of the line cord is then inserted into the wall socket. The line switch is turned on and the pilot light on the instrument panel should light up. After one to two minutes, required for the thyratrons to heat up, the apparatus is ready for use. This pause can be used for connecting the electrodes. Both pairs of electrodes are attached to the corresponding terminals on the instrument.

The inactive electrode is attached to the patient as a rule by using a piece of warm, moist cloth larger than the size of the electrode. The switch for the output terminals is set to position I or II, depending on the method used for beginning the study. The polarity switch is set to the "normal" position.

When beginning the test, the current switch is set to the operating position "G-5" or T-10", depending on which current is to be used for beginning the study. An effort is made to begin the study at low currents so that the "G-5" or "T-10" positions are used.

If this proves to be insufficient, the switch is adjusted to positions which allow stronger currents to be used ("G-50" and "T-50"). The potentiometer knob must be used to adjust the current intensity, with the motion of the milliammeter needle being observed carefully. Later on during the investigation, the current is increased or decreased by moving the potentiometer knob, changing the type of current, switching the leads to the patient when changing to another method of investigation, etc.

It should not be forgotten that the setting of the current selector to another position in any case, even when merely changing the limits of the current intensity, e.g., from "G-5" to "G-50" or from "T-10" to "T-50", or vice versa, can only be done after turning the knob of the regulating potentiometer to the zero position.

§ 4. APPARATUS FOR STUDYING ELECTRICAL EXCITABILITY; ELECTRICAL PULSE GENERATOR EI-1

This instrument was developed by VNIIMIO and is being manufactured by the Union Factory of EMA. It is a generator of pulsed and constant (galvanic) current, intended for a complete range of investigations dealing with electrical conductivity of nerve and muscle systems in the body, by means of square wave pulses in regimes of both single and repeated stimulation (the former being used to obtain a curve showing intensity as a function of duration and chronaximetry, and the latter used to determine lability).

The generator provides rectangular current pulses which pass through an object, independently of the magnitude and nature of its resistance. Such generators are called "generators with constant current output". An apparatus of this kind differs from other pulsed current generators, in which the rectangular pulse is usually formed only as voltage pulses at the output terminals of the apparatus (the shape of the current pulses then changes somewhat, as shown in Fig. 98), so that they are referred to as "generators with a constant voltage output".

The repetition frequency of the pulses is adjustable within /128
a range of 0.5 to 2500 Hz, in 22 stages (two ranges of 11 steps

each). The deviation of the frequency from the nominal value does not exceed ± 5%.

The pulse duration is adjustable from 0.02 to 100 msec in 10 stages. The permissible deviation of the pulse duration from nominal value is ± 10%. Independent adjustment of frequency and duration within the limits of spacing is at least 2.5.

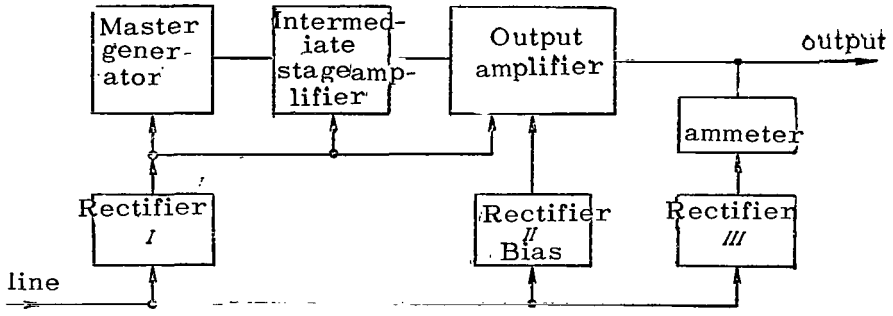


Fig. 112. Block Diagram of EI-1 Electric Pulse Generator.

The possible deviation in duration, frequency, or amplitude of the pulses from a nominal value with a change in the line voltage from -10 to +5% does not exceed ± 5%. Within these limits, however, it is possible to have a change in the indicated values when tubes are replaced in the apparatus.

The maximum value for the galvanic or pulsed current (in the latter case, in amplitude value) with a load resistor of 4000 ohms is 45 mA. The current in the load circuit is smoothly regulatable from zero to a maximum. The apparatus is equipped with a device for measuring the galvanic current and the amplitude values of the pulsed current with two measurement ranges: 0-5 and 0-50 mA. The measurement error for the galvanic current is ± 5% at the maximum, while that for pulsed current has a maximum of ± 10%.

The apparatus can be connected to a wall socket supplying 127 or 220 V, and consumes a maximum of 100 VA. The overall dimensions of the instrument are 430 × 270 × 285 mm, and the entire apparatus weighs 16 kg.

A block diagram of the apparatus is shown in Figure 112, while the schematic diagram is shown in Figure 113. The instrument consists of the following separate units: the master generator, intermediate amplifier, output amplifier, current-measuring section, and three rectifiers.

The master generator includes a multivibrator with self-excitation using the 6N8 (V_1) tube. The generator provides impulses

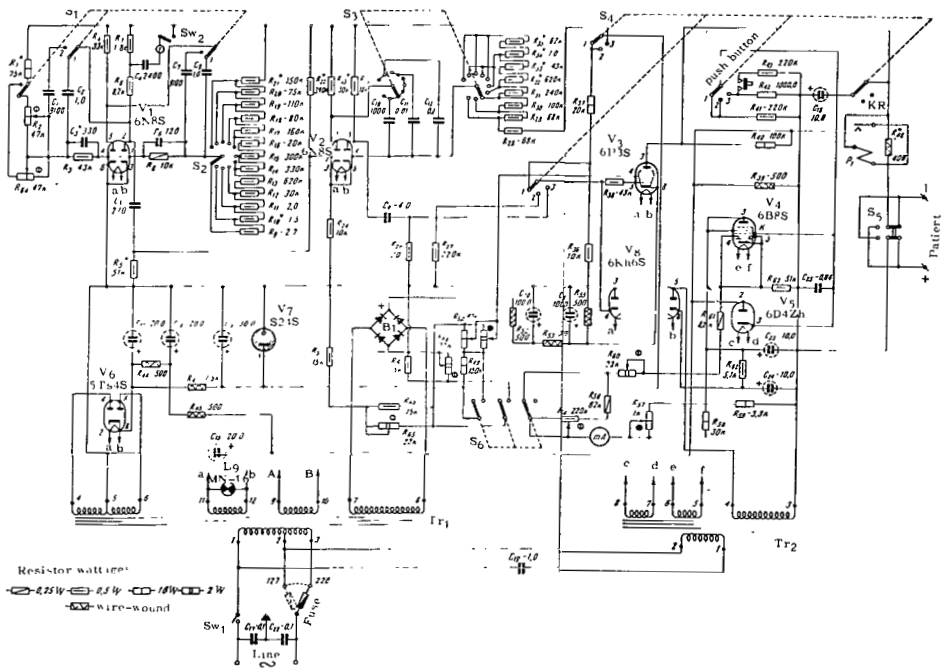


Fig. 113. Schematic Diagram of EI-1 Electric Pulse Generator.

which are nearly rectangular in shape and whose frequency is adjusted by means of a system for switching capacitances and resistances in the arms of the multivibrator. The change in the adjustment range for the pulse frequency by a factor of 100 is accomplished by switch S_1, which is used to switch capacitances 1-2 and 7-8 in the grid circuits of the two triodes, as well as the regulated (trimmer) resistors 2 and 64 in one of the arms of the multivibrator. The fine step-wise adjustment of the frequency within the limits of each range is accomplished with the aid of switch S_2 for resistors 9-21 in the other arm of the multivibrator. To increase the steepness of the pulse front, the grid circuits of the multivibrators contain resistors 3 and 8, shunted by capacitors 3 and 6.

The anode circuit of one of the triodes of the multivibrator contains an earphone T with switch Sw_2, which permits the frequency regime of operation to be monitored by ear.

The pulses from the master generator pass through a differentiating circuit consisting of capacitor 5 and resistor 5, and are transformed into brief (about 10 μsec) sharp-peaked positive pulses, which reach the grid of the intermediate stage tube. This stage consists of the multivibrator with independent excitation or the "trigger generator", which operates with the dual triode 6N8 (V_2). The multivibrator, locked by a negative bias, is connected by resistor 24 to the grid of the left-hand triode, which is opened by pulses from the master generator. The pulse duration of the multivibrator can be adjusted step-wise by switching capacitors 10-12 and resistors 28-35, by means of switch S_3. /129

Pulses of variable duration, obtained at the output of the multivibrator, pass through the separating capacitor 9 to the control grid of the output amplifier. The output amplifier consists of a beam tetrode 6P3 (V_3), which operates with a considerable independent negative bias on the grid, produced by rectifier Re_1. To ensure that the amplitude of the pulses passing through the separating capacitance will be independent of their constant interval, their component is produced by means of a diode (left half of tube 6 × 6 S, shown as V_8 in the circuit), connected between the grid and the cathode. The amplifier tube operates in a regime of pulse amplitude limitation by grid current, thus ensuring a rectangular pulse shape (flat top).

The change in type of current is achieved with switch S_4, which has three positions: 1, galvanic current; 2, open-circuit or zero current, and 3, pulsed current. In the galvanic-current regime, the master and trigger generators are disconnected, and a constant positive potential from the voltage divider using resistors 36 and 37 is applied to the grid of the output tube. The switching of the tube grids is accomplished on the second level of switch S_4; any one of the following can be connected to the grid: an average current from the voltage divider (galvanic), a connection from the separating capacitor (9) (pulsed), or a leak resistor (27) (zero position).

To produce a "constant current" output, a load is connected in series in the anode circuit of the output tube, which must have a high internal resistance. In this case, the nature of the load resistor, e.g., its capacitance component, will have a much less marked influence on the shape of the current pulses. In this particular case, the anode circuit of the output tube contains the contacts of polarity switch S_5, to which are connected the output terminals. The anode circuit of tube V_3 runs from a separate filter in the rectifier circuit (resistor 45) through resistor 39 of the current-measuring system, the contacts of switch S_5, the winding of protective relay R_1, (shunted by resistor 48), and to the anode of the tube. This circuit is shunted by a high value resistor 40, through which the circuit of the output tube is passed when there is no load connected to the output terminals. When relay R_1 operates, as occurs when the current in the output circuit is greater than 50 mA, the contacts of the relay KR quickly connect the output terminals to resistor 39.

The cathode circuit of tube V_3 is connected to a ripple filter (capacitors 20-21 and resistors 52-53) and rectifier B_1, to form an independent bias on the grid of tube V_3, whose negative side is connected to the common negative of the entrire circuit.

Regulation of the current (amplitude of current pulses) in the load connect to the output terminals of the apparatus is achievied by regulating the voltage applied to the screen grid of the output tube by means of potentiometer 50. To protect the patient receiving treatment in case the contact in the potentiometer is broken, the latter is double (47 kΩ in each section). Potentiometer 50 is connected in series with resistors 49, 65-66, and 51, to form a voltage divider. When switching the current regulation range from 0-5 to 0-50 mA, which is done by means of switch S_6, the contacts of the latter are shorted by resistor 49, while resistors 51 and 65-66 shunt the circuit consisting of resistors 67-68. The third system of contacts on switch S_6 then open the circuit which has shorted resistors 54 and 56 (a current of 0-5 mA), which are connected in series in the circuit for the current-measuring device. /130

The current measuring device consists of a peak voltmeter, which measures a voltage drop across resistor 39; the latter is directly proportional to the current in the load circuit. The scale of the instrument is graduated in amplitude value of current pulses. A simplified diagram of the current measuring device is shown in Figure 114. The heart of the apparatus is a bridge for measuring the voltage across the terminals of capacitor 25, which is charged by diode V_5 from the voltage formed across measuring resistor 39 when a current pulse passes through it. Thanks to the diode, the capacitor almost does not discharge at all during the pauses between pulses. (To prevent discharge of the capacitor by line current and the leakage current, a type 6B8 tube is used with an output using a balloon grid, operating with reduced heating on the order of 4-4.5 V). Under these conditions, the voltage at the capacitor

terminals will be directly proportional to the amplitude value of the current pulses, passing through resistor 39; howeve, it will depend to a certain degree on the interval between the pulses, which is taken into account by means of suitable corrections.

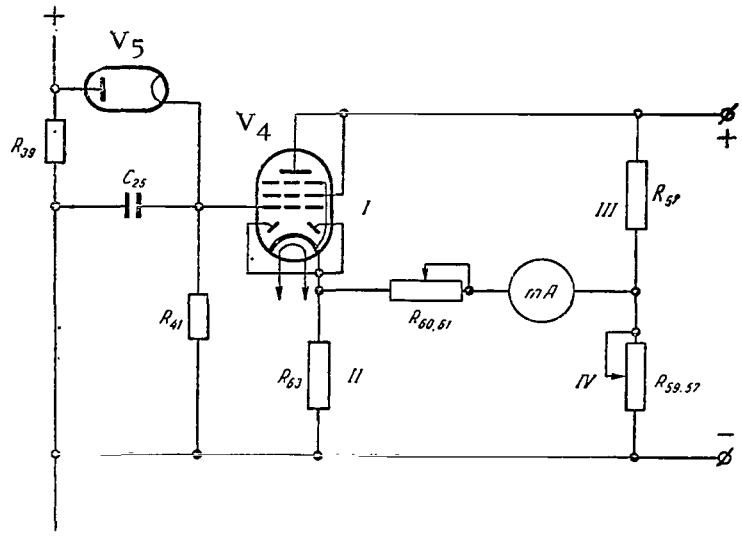


Fig. 114. Simplified Diagram of the Current Measuring Device in the EI-1 Electric Pulse Generator.

The voltage formed in capacitor 25 is then passed to the grid of the measuring tube V_4, which is connected to one of the arms of the bridge. The remaining three arms of the bridge consists of resistors, as shown in the circuit (Fig. 114). A microammeter "mA" is connected diagonally across the bridge. To obtain true current values, a correction must be applied to the readings of the instrument; this correction is based on tables located on the control panel below the indicator. /131

To return the pointer to zero rapidly, it is necessary to press button KN, which shunts resistor 43 across capacitor 25 (see Fig. 113); the correction of the zero position of the pointer is accomplished with potentiometer 57.

The instrument is powered by three rectifiers. The first powers the entire generator section of the apparatus, including the output tube. The rectifier operates with a 5Ts4S (V_6) tube, in a full-cycle configuration. The power for the master and trigger generators, as well as the voltage divider for the screen circuit of the output amplifier is stabilized by a stabilitron SG4S (V_7); the power for the anode circuit of the output amplifier comes from a separate decoupling filter (capacitors 13-14, resistors 44 and 45).

The second rectifier B_1, using a bridge circuit made of selenium elements, and including a ripple filter (capacitors 20-21,

resistors 52-53), is used to apply an independent bias to the control grid of the output amplifier. Both rectifiers operate from the same transformer.

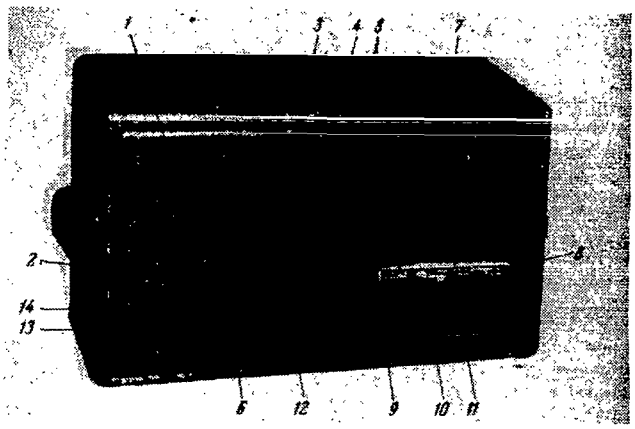


Fig. 115. General View of EI-1 Electric Pulse Generator.

The third rectifier consists of a half diode 6 × 6 (V_8) and supplies the current measuring device. To stabilize the voltage, the rectifier operates from a separate ferroresonance transformer, whose primary winding is connected to the circuit in series with a capacitor (in a series resonance circuit).

The parts data are given on the diagram.

An overall view of the instrument is shown in Figure 115. It is mounted in a rectangular cabinet. The front of the cabinet serves as a control panel. In the upper right corner of the panel is the indicator (7) with a table of corrections (8) below it. Below the table, from left to right, are the following: switch (9) for selecting the measurement ranges of the apparatus (0-5 and 0-50 mA), knob (10) for adjusting the zero position of the pointer, and button (11) for returning the pointer rapidly to zero, as well as the output terminals.

On the left side of the panel, at the top, are the following: /132 knob 1 for fine adjustment of frequency, knob 3 for adjusting pulse duration, and speaker 8. In the center are knob 2 for adjusting the frequency range, knob 4 for selecting the type of current, and switch 8 for the speaker. At the bottom are lens 14 for the pilot light and line switch 13, as well as knob 6 for adjusting the current in the circuits leading to the patient, and polarity switch 12.

The arrangement of the parts on the chassis is shown in Figure 116. At the right is the power transformer 11, with the vacuum tubes next to it: output tube 16, kenotron 18 of the basic rectifier,

stabilitron 15, and tubes 14 and 17 of the multivibrators. At the right, near the control panel, is a plate 12 on which are mounted the resistors and capacitors in the multivibrator circuits. Below them, on the other side of the control panel, are the switches for frequency and pulse duration. Near panel 12, at the left, is the speaker 10. Further to the left along the control panel is meter 7. On the left-hand side of the chassis are the ferroresistance transformer 1 and the current-measuring tubes: 2 (6 × 6), 3 (6B8) and 4 (6D4Zh). Near them are the knobs for adjusting the resistors in the measurement circuit. Capacitors 20 are located in the middle of the chassis.

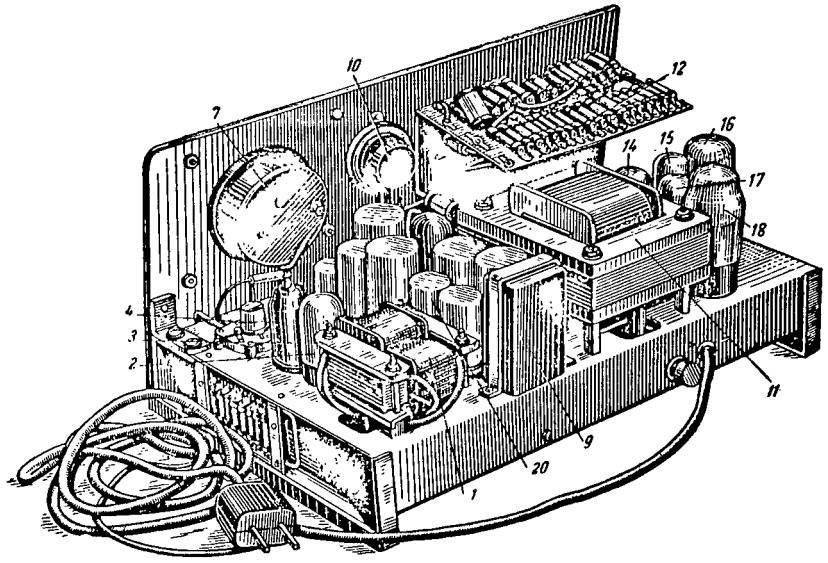


Fig. 116. Location of Parts in the EI-1 Electric Pulse Generator.

The material supplied with the apparatus includes the following:

1. The instrument itself, including tubes.
2. A box containing the following electrodes: (a) single pole electrode-buzzer, (b) bipolar electrode-buzzer, (c) electrode for chronaximetry, (d) plastic (inactive) electrode.
3. Wire with clamp, rubber straps (2).
4. Technical description, certificate, and instructions for use.

The instrument is intended for rather detailed studies of electrical excitability. The method for carrying out these studies has been described in the instructions which are provided with the apparatus, which must be followed. We will mention only that before plugging the apparatus into the wall, it is necessary to ensure that the knobs for adjusting the type of current and for the regulating potentiometer are set to zero. After plugging the apparatus /133 in, and prior to beginning the study, the apparatus must be allowed to warm up for 4-6 min. While performing the study, it is important

not to forget that before changing the type of current or the range of measurement (0-5 and 0-50 mA), regardless of the type of current, the knob of the regulating potentiometer ("patient current") must be returned to zero (all the way to the left). After each adjustment, it is necessary to check the zero position of the pointer on the milliammeter.

§ 5. APPARATUS FOR ELECTRICAL STIMULATION OF MUSCLES (ASM-3)

This instrument is intended for electrical stimulation of damaged muscles, as well as for studying their electrical excitability in order to select the most effective type of current for electrical stimulation. The instrument was developed in the course of the modernization of the model of the instrument which was formerly produced and called the ASM-2 (see the second edition of this book, 1960). It is a pulsed-current generator, with variable frequency and pulse duration, which can be adjusted to deliver either rectangular or exponentially increasing wave forms, with a possibility for regular or irregular modulation of pulse amplitude (individual accelerations of desired duration). An example of the appearance of pulsed current from the ASM-3, with exponentially rising pulses, is represented schematically in Figure 117.

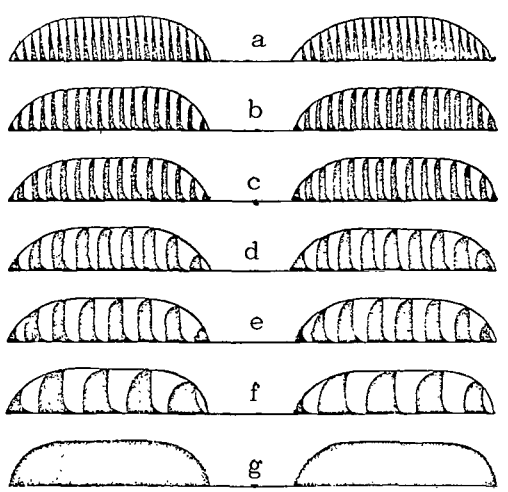


Fig. 117. Schematic Representation of Modulated Pulsed Current.

The basic data of the apparatus are the following: pulsed current (exponential or rectangular shape) is regulated in nine stages with the following frequency and duration characteristics.

The ninth stage is galvanic current.

The maximum value for the currents indicated above, when a 4000 ohm resistor is connected to the output of the apparatus, is as follows: for galvanic current, 30 mA; for pulses in stages 1-6, 30 mA; for pulses in stages 6-9, 40 mA.

TABLE 13

Step	Duration in msec	Frequency in Hz	Step	Duration in msec	Frequency in Hz
1	60	8	5	12	30
2	40	12	6	8	40
3	30	16	7	5	60
4	25	20	8	3	80
			9	2	100

All of the types of current mentioned are regulated by a single output potentiometer, but in two ranges from 0 to 10 mA and 0 to 50 mA on two indicator scales. The latter are graduated in amplitude value of current pulses. The instrument permits both a constant application of any of the currents described above to the output terminals, as well as their rhythmic modulation at different frequencies or a gradual rise in amplitude. The frequency of the rhythmic modulations is smoothly adjustable from 12 to 32 pulses per minute. The ratio of the triggering pulse duration and the pause at low modulation frequencies is 1 to 1.5; at medium frequencies it is 1 to 1 and 1.5 to 1 at high frequenices. /134

It is also possible to achieve manual modulation of the pulse current in the form of individual (single) pulses of any duration for active stimulation.

The apparatus is provided with a relay for limiting the maximum current in the patient circuit to 50 mA.

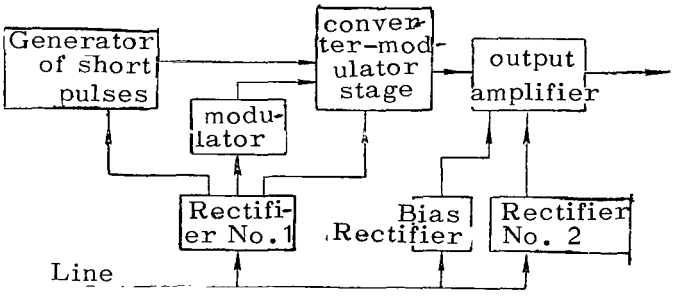


Fig. 118. Block Diagram of Apparatus for Electrical Stimulation of Muscles, ASM-3.

The dimensions of the apparatus are 380 × 280 × 215 mm. The weight of the instrument and attachments is 15 kg.

A block diagram of the apparatus is shown in Figure 118, while the schematic diagram is in Figure 119. The instrument consists of the following main units: a generator of brief current pulses, a generator for long pulses or modulator, a converter-modulator stage, output amplifier, two rectifiers in the power circuit and a third for supplying a bias to the output tube grid.

The generator of brief pulses consists of a multivibrator with self-excitation and positive grids (see Fig. 104), using a 6N1P (V_1) tube. The generator provides unilateral pulses which are nearly rectangular. Changes in the frequency and spacing of the pulses (and consequently their duration) are accomplished step-wise by changing the value of the resistors connected between the grids

and the positive pole of the power source. Resistors 1-10 are attached to the first plate and 14-30 are attached to the second plate of switch S_1.

Switch S_1 has 10 operating positions; nine of them are for pulsed current, marked in the diagram according to the frequency of the pulses, while the tenth position is marked "zero "for galvanic current. In this position, the grids of the multivibrator receive a negative potential from the rectifier and the tube closes. The cathode circuit contains a resistor 13 (which can be adjusted inside the instrument); this resistor is used to set the operating regimes of the two triodes in the multivibrator. The grids of the multivibrator are connected to capacitors 1 and 2; the anode circuits contain resistors 11 and 12.

The pulses from the multivibrator pass through the separating capacitor 3 to the first grid of tube 6P15P (V_3) in the converter-modulator stage. A leak resistor 44 is connected to the grid. /135

The long-pulse generator (modulator) consists of a multivibrator with self-excitation, with a positive bias on the grids (see Fig. 103), and consists of a 6N1P (V_2) tube. The pulse frequency can be adjusted smoothly by changing the bias potential on the tube grids by means of potentiometer 34. The arms of the multivibrator contain capacitors 4-6 and resistors 38-40. Resistor 40 serves to balance the operating regime of the multivibrator triodes, and is adjusted inside the instrument.

The pulses from the modulator pass through the separating capacitor 8, resistors 43 and 86 (the latter is adjustable inside the apparatus) and the contacts of switch S_4 (rhythmic or manual modulation). They then go to the third grid of tube 6P15P (V_3) in the converter modulator stage. The separating capacitor converts the pulses to bilateral ones. Only the negative part of the pulse reaches the grid of tube V_3. The positive part of the pulse passes through diode D_2.

Hence, the modulation of short pulses is accomplished by feeding the negative potential to the third grid of tube V_3, thus lowering the pulse amplitude or completely closing the tube and preventing transmission of brief pulses to the output. When the modulator is disconnected, which can be done by using switch Sw_2, which operates when the knob of potentiometer 34 is in its extreme position, pulsed current is supplied continuously to the output (without modulation).

The negative pulses in the modulation are smoothed at the beginning and end of the pulse by means of capacitor 7, connected by leak resistor 45 to the tube grid. This permits a gradual increase and decrease of the pulse amplitude during modulation. The second (screen) grid of tube V_3 is supplied with a positive potential through damping resistor 46. The operating regime of the tube provides

a strictly rectangular shape for the brief pulses in the anode circuit of the tube.

The short rectangular voltage pulses, modulated in amplitude, are obtained from resistor 47, connected to the anode circuit of tube V_3, and then pass between the grid and the cathode of the output amplifier tube 6P13S (V_4). On the grid of the tube, they pass through separating capacitor 9 and then go either directly through the contact of switch Sw_3 (retaining their rectangular form) and resistor 60, or they go through the shaping circuit, which gives them an exponential shape (the contacts of Sw_3 are then open). On the cathode of tube V_4, the pulses pass through terminals 6, the transformer winding which powers the rectifier using the diodes D_3-D_4 and resistors 67 and 62. The rectifier supplies an independent negative bias to the grid of the output tube. Capacitor 12 is used for filtering the output from this rectifier. Resistor 47 is a potentiometer which can be used to modulate the pulsed current manually. Switching with rhythmic manual modulation is accomplished with switch S_4. In the position for rhythmic modulation, it connects the third grid of tube V_3 with a modulator, and also connects the lower contact of potentiometer 47 to the cathode of the output tube V_4. In the position for manual modulation, it disconnects the modulator but the cathode of tube V_4 is switched to the wiper of the potentiometer. With a zero position of the wiper (the top contact of potentiometer 47), to which it is returned by a spring, no impulses reach the grid of tube V_4. As the knob of potentiometer 47 is turned, the amplitude of the pulse transmitted to the grid of the output tube /136 gradually increases. This is how manual modulation is accomplished.

To retain the unipolarity of the pulses passing through the separating capacitor (9), diode D_1, which passes the portion of the pulse which has the opposite sign, is connected in parallel.

The shaping circuit consists of capacitors 10 and 11 and resistors 49-57, which are connected to the third and fourth plates of switch S_1. In the galvanic current regime, the shaping circuit is disconnected and the constant positive potential passes through the zero contacts on the fourth plate to the grid of the output tube.

Finally, the shape, modulated, and amplified pulses from the output tube appear across the regulating potentiometer 65, which is connected to the cathode circuit of the tube. An additional resistor 63, of fixed value, is connected in series with potentiometer 65; this resistor 63 is shunted by the contacts of switch S_3 when making a change over to a regime with higher currents (0-50 mA). The second pair of contacts of switch S_3 likewise switches the banks of shunts for the milliammeter: resistors 72-77, 78-80, and 81-85. The pulsed current reaches the output terminals through the milliammeter with its shunts and the polarity switch S_2.

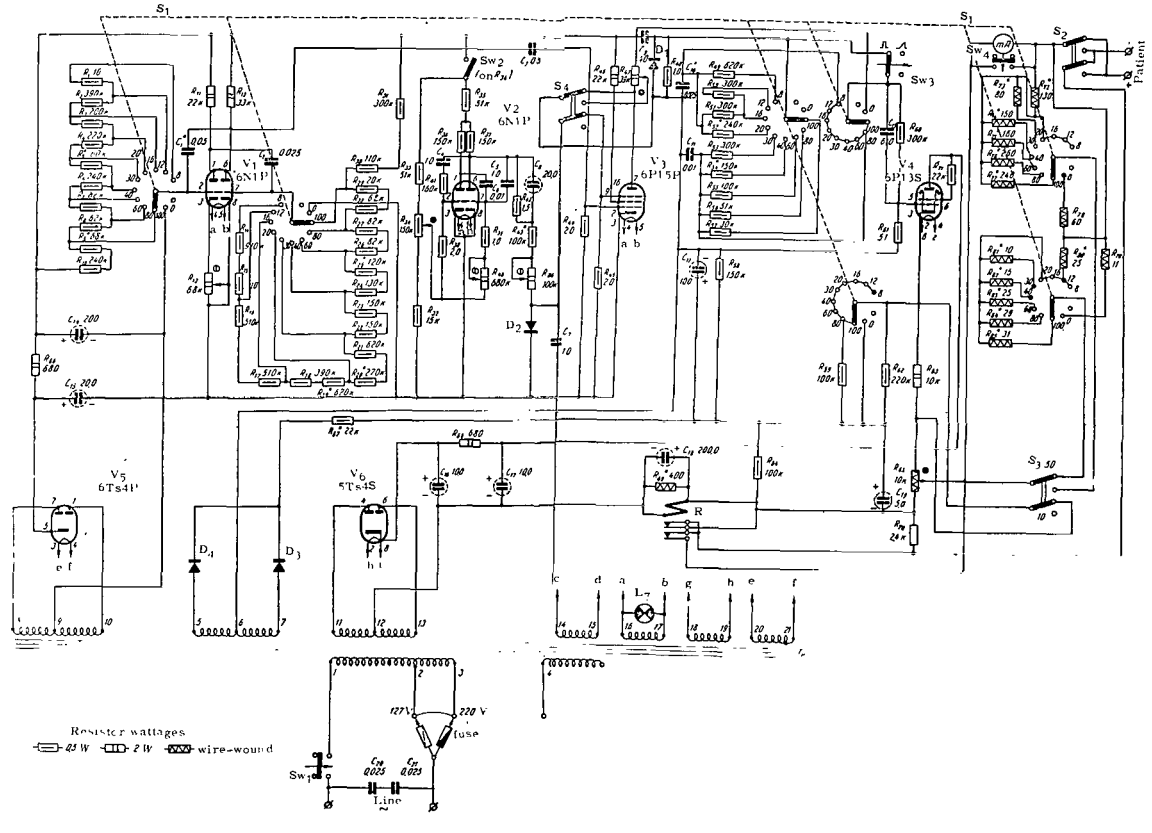


Fig. 119. Schematic Diagram of ASM-3 Apparatus for Electrical Stimulation of Muscle.

The negative lead of the power circuit for the output tube V_4 contains relay R, which operates when the current in the patient circuit increases beyond normal levels; it acts first of all to disconnect the circuit from the output terminals rapidly, thus reducing the voltage connected to the patient; secondly, it cuts limiting resistor 70 into the short circuit in series with the output potentiometer.

The generator of brief pulses, the modulator, and the converter-modulator stage are powered by rectifier No. 1, which uses kenotron 6Ts4P (V_5); the output amplifier stage uses rectifier No. 2, consisting of tube 5Ts4S (V_6).

The data on the electronic components are given on the schematic diagram.

A general view of the apparatus is shown in Figure 120. The instrument is contained in a rectangular cabinet, on the top of which is a handle for transporting it. The front of the cabinet serves as a control panel. In the middle of the panel is the milliammeter (5); to the left of it at the top is the lens (2) of the pilot light and the switch (3) for selecting the levels of current to be regulated (10-50 mA). In the center is line switch (1) and milliammeter switch (4). On the right is the polarity switch (6), the switch for shaping the pulses (7), and the output terminals (8). At the bottom of the panel at the left is knob (13) for regulating the frequency of rhythmic modulation, knob (12) of the potentiometer for manual modulation, knob (11) for the output potentiometer, switch (10) for manual or rhythmic modulation, and knob (9) of the switch for selecting the type of current. The scale of the latter is graduated in pulse frequencies.

Figure 121 shows a view of the apparatus with the cabinet removed. The parts are mounted on a horizontal chassis and on the back of the control panel. On the back wall of the chassis at the bottom is a socket (1) for connecting the line cord and a switch (2) for selecting the line voltage (127/220 V) with a fuse. The control panel carries a switch (14) for selecting the currents, output terminals (17), milliammeter (12), line switch (3), socket (4) for the pilot light, and other components. In the middle of the chassis is transformer (16), on top of which is panel (11) with resistors mounted on it. To the left of this is a group of electrolytic capacitors (13), and vacuum tubes to the right of them. The latter include the output tube (5) (6P13S), kenotron (6) of the rectifier which powers the output amplifier, kenotron (7) of /137 the rectifier which powers the generator section of the apparatus, tube (8) (6P15P) for the converter-modulator stage, and tubes (9) and (10) (6N1P) for the generators of short and modulating pulses. The entire assembly and other parts can be removed from the bottom of the chassis.

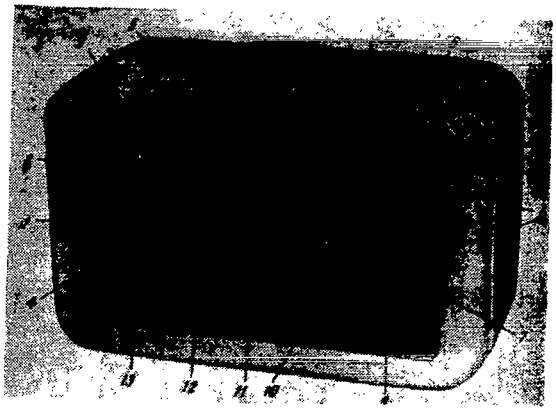


Fig. 120. General View of ASM-3 Apparatus.

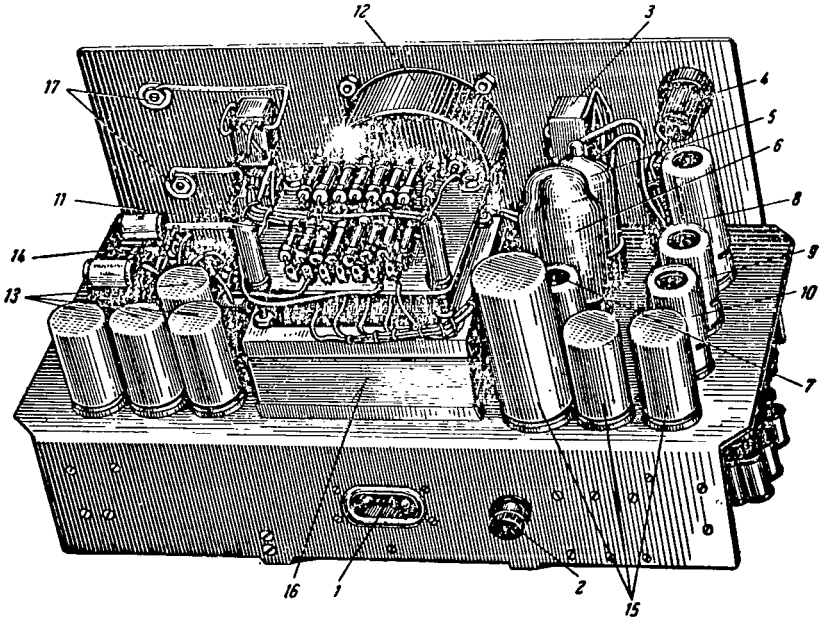


Fig. 121. Arrangement of Components in ASM-3.

The equipment supplied with the apparatus includes the following:

1. Single-pole pointed electrode with cord, 2m long.
2. Bipolar point electrode, with adjustable jaws and wire 2 m long;
3. Lead electrode, 15 × 20 cm^2; supply of pairs of lead electrodes, with leads 2 m long, measuring 1 × 1 cm^2; 1 × 2 cm^2, 3 × 4 cm^2, 4 × 6 cm^2, 6 × 10 cm^2; /138
4. Wire, 2 m long, with spring clips (2); rubber straps (2);
5. Line cord;
6. Technical description, instructions for use, and certificate for the apparatus.

The apparatus should be checked before beginning the treatment. Prior to inserting the power plug into the wall, it is necessary to ensure that the line switch is in the "off" position, the knob of the current-selector switch is at 10 mA, the knob "patient current" is in the zero position, the polarity switch is in the "direct" position, the knob of the modulator switch is in the position "rhythmic modulation", the knob of the rhythmic modulator is in the "without modulation" position, the current selector switch is in the "zero" (galvanic current) or "100" (tetanizing current). The apparatus is plugged into the wall by means of a separate cord with a plug and socket for attachment to the prongs in the socket on the chassis of the apparatus. When the line switch is thrown, the pilot light comes on. After 1-2 min, required for heating the tubes, the apparatus is ready for use.

In conducting electrical stimulation, it is necessary first of all to determine the nature of the pulsed current to be used. Therefore, after placing the electrodes on moist cloth located on the corresponding part of the body, and having connected them to the apparatus, it is necessary to test the stages of the pulsed current one after the other, beginning (depending on the nature of the affliction) either with the shortest pulses of tetanizing current or (on the other hand) with galvanic current and long pulses. The electrodes used are usually the point type (unipolar or bipolar) with a manual switch, as in electrodiagnostics. The knobs of the switches and regulating devices on the instrument must be set to the initial position as described above; the current then goes to the output terminals without modulation and is controlled by a button on the electrode. The regulating potentiometer is then used to intensify the current and the nature and force of the contractions of muscles are observed; these include both threshold contractions and the maximum contractions which can be produced without causing the patient any particular pain. The corresponding values of the current are noted on the apparatus. Then, returning the potentiometer to the zero position, the current selector switch is turned to the next position and the potentiometer knob is turned once again to determine the value of the current for threshold and maximum contraction. By repeating this test at a number of stages and comparing the nature of the reactions, the force and pain produced by

the maximum contraction, we can determine the degree of pulsed current which is most effective under the given circumstances.

If the experiments indicate that a current between 0-10 mA (according to the instrument) is insufficient, we can switch knob 3 for the current level to 0-50 mA, being very careful that we first turn knob 11, which regulates the current in the patient's circuit, to the zero position. It must not be forgotten that knob 3 changes not only the value of the scale divisions of the milliammeter, but also the voltage applied to the output potentiometer. This means that the current flowing in the patient's circuit at the same setting of knob 11 of that potentiometer will increase severalfold. Hence, if we do not turn knob 11 of the potentiometer to the zero position and switch knob 3 for the current level, the patient will receive a sharp, painful and traumatic jolt of current. To carry out rhythmic stimulation, flexible electrodes are fastened to the location with cloths of the corresponding size; they are then connected to the apparatus and the knob for adjusting the modulation frequency is set to the position corresponding to the desired rhythm of contractions and relaxations of the muscles. Then knob 11 of the potentiometer is gradually advanced to intensify the current, being careful to move the potentiometer knob only during the greatest contraction of the muscles. The contraction rhythm is simultaneously determined. /139

If we try a number of stages of pulsed current and do not succeed in obtaining sufficient contraction of the damaged muscles, we must attempt to accomplish this by means of a slight shift in the position of the electrodes. It should be mentioned that the conduct of the electrostimulation process, particularly at the beginning of therapy, requires considerable attention, care, and patience.

In performing active stimulation (with the electrodes located in the same position as in rhythmic modulation) the controls for manual modulation located on the control panel are used to deliver a current pulse. Knob 13 of the rhythmic modulator is set to the "off" position, while knob 10 is set to the "manual" position. It is then necessary to overcome the resistance of the spring and turn knob 12 of the manual modulator clockwise to the extreme right-hand position. Simultaneously, knob 11 (which must be set to the zero position when the other knobs are in the position described above, is used to deliver a current to the patient's circuit which is sufficient to obtain effective contraction. Knob 12 is then gradually turned back to the zero position while knob 11 remains at the former setting. Now, in order to produce muscle contractions during exercise, it is sufficient merely to turn knob 12 of the manual modulator clockwise all the way, keep it there for the required time and then return it to the zero position rapidly.

§ 6. APPARATUS FOR THERAPY BY SINUSOIDAL PULSES; SNIM-1

This device was developed and is being produced by the Union Factory of the EMA. The factory designation of the apparatus is "apparatus for low-frequency therapy by sinusoidal modulated pulses". The author's terminology, which gives the method of therapy, would call this an apparatus for therapy by means of diadynamic currents. This instrument belongs to the group of electrical stimulators, but it is intended primarily for work with the sensitive and trophic area of the nervous system, especially for treating various illnesses which are accompanied by muscular spasms. Experiment has shown that the currents used in this apparatus have a sedative, antispastic, and antiedematic effect.

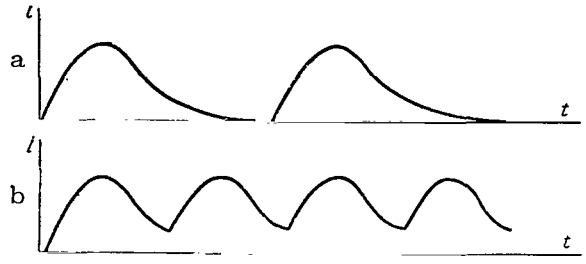


Fig. 122. Shape of Current Pulses in Apparatus for Therapy by Diadynamic Currents (SNIM-1).

The apparatus is a generator of pulses of electric current of constant polarity, with a somewhat altered sinusoidal shape, frequencies of 50 and 100 Hz, and a duration of 0.01 sec. These pulses can be modulated rhythmically in amplitude to produce pulses of different duration, and with different alternations of pulses with frequencies of 50 and 100Hz.

The shape of the pulses at a frequency of 50 Hz is shown in Figure 122, a. These pulses are sinusoidal, obtained by half-cycle rectification of alternating line current, in which a capacitor with a constant discharge time has been suitably located in the circuit; this discharge time is 4 msec, and the descending part decreases exponentially. At a frequency of 100 Hz, similar pulses are obtained by full-cycle rectification of the line current, and have the shape shown in Figure 122, b. /140

This apparatus provides two basic forms of pulses of therapeutic current: Regime I is the "constant pulse shape" and Regime II consists of "variable pulse shapes". In the first case, the following seven different types of current can be obtained:

(a) "Half-wave DC", with pulses at a frequency of 50 Hz delivered continuously (Fig. 123, a and 122, a). /141

(b) "Full-wave DC", with pulses at a frequency of 100 Hz delivered constantly (Fig. 123, b and 122, b).

(c) "Syncope-rhythm current", with pulses delivered at a frequency of 50 Hz constantly, with a pulse duration of 1 sec and a period of 2 sec (Fig. 123, c).

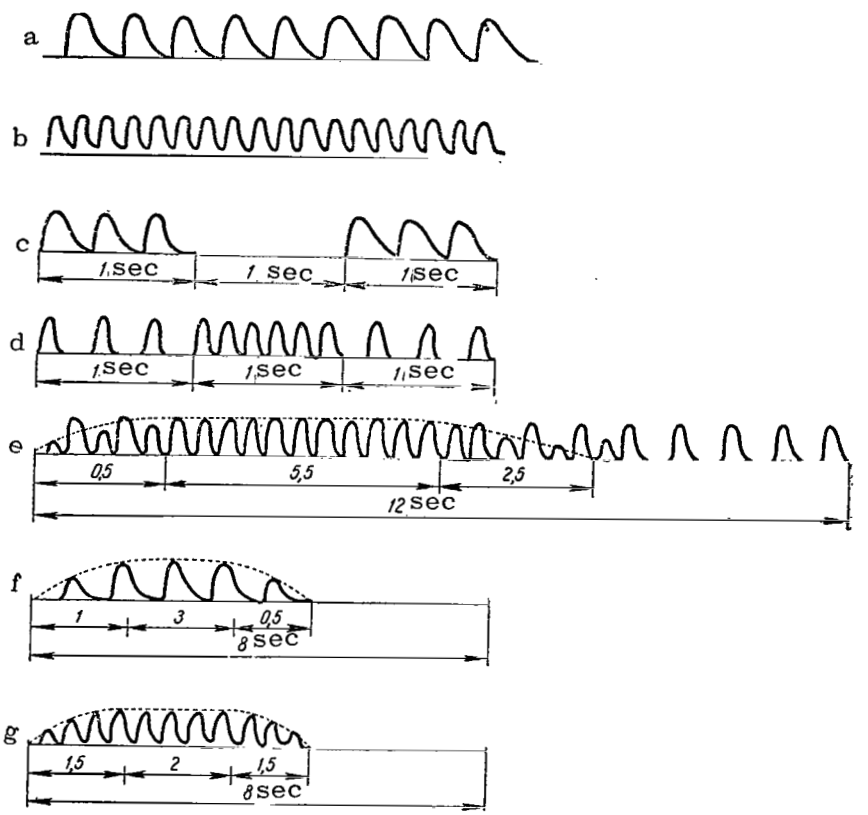


Fig. 123. Shape of Current Pulses in the SNIM-1 Apparatus.

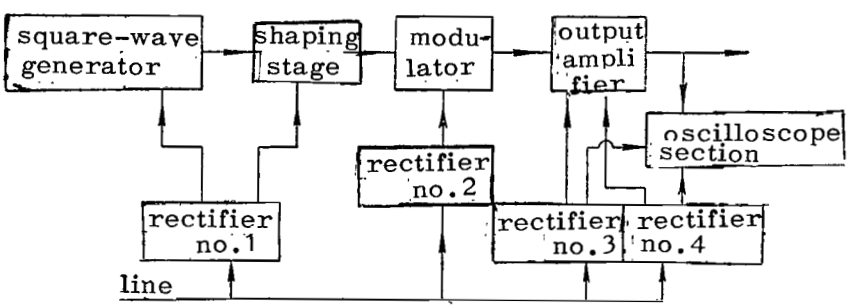


Fig. 124. Block Diagram of SNIM-1 Apparatus.

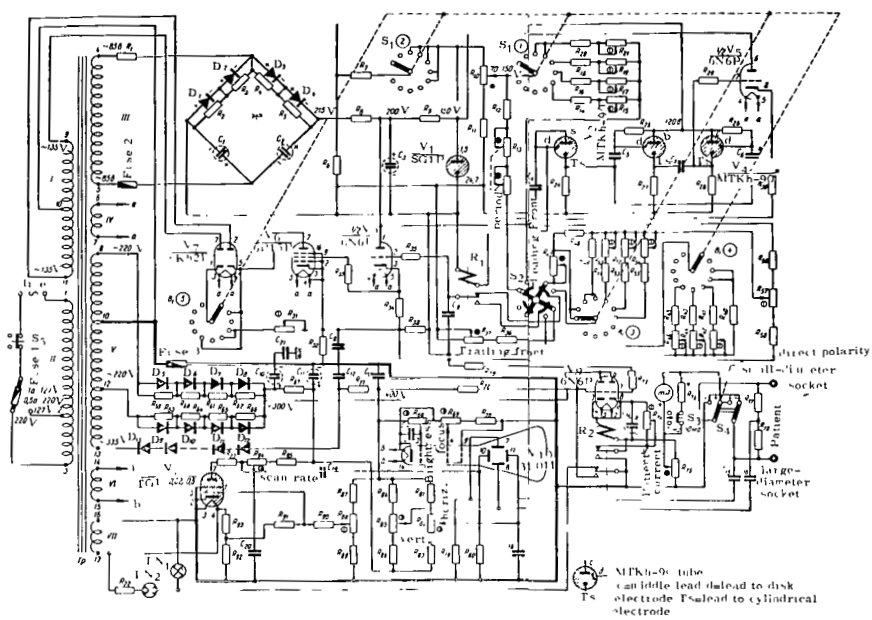


Fig. 125. Schematic Diagram of SNIM-1 Apparatus for Therapy by Diadynamic Currents.

- ● knob located on contol panel of apparatus
- ◑ knob on side of apparatus
- ⊕ adjustment made inside cabinet
- ⁎ variable resistor for adjustment

(d) "Short-period current", alternating-current pulses with a frequency of 50 and 100 Hz, and a duration of 1 sec (Fig. 123, d).

(e) "Long-period current"; these are stimuli consisting of pulses at a frequency of 100 Hz, in which pulses with a constant amplitude alternate with pulses whose amplitude is modulated, i.e., increases and decreases periodically (Fig. 123, e). The period of the stimulus is 12 sec. This consists of 0.5 sec during which the intervening pulses increase in amplitude, 5.5 sec during which there are pulses at a frequency of 100 Hz, 2.5 sec during which the amplitude of the pulses decreases, and 3.5 sec during which there are pulses at a frequency of 50 Hz.

(f) "Half-wave alternating current", interrupted transmission of pulses at a frequency of 50 Hz with amplitude modulation (Fig. 123, f). The period of the stimulus is 8 sec. This consists of 1 sec rise time, 3 sec at maximum amplitude, 0.5 sec for decreasing amplitude, and 3.5 sec pause.

(g) "Full-wave alternating current"; discontinuous transmission of pulses at a frequency of 100 Hz, with amplitude modulation (Fig. 123, g). The period of the stimulus is 7 sec. This consists of 1.5 sec of rise time, 2 sec at maximum amplitude, 1.5 sec for a drop in amplitude, and 3 sec pause.

In the regime "variable stimulus shape", all of the forms of current except the first two listed above are provided, i.e., with uninterrupted transmission.

This means that it is possible to have a smooth regulation of both the period of all stimuli within limits from 1-20 sec (or the stimulus frequency within limits of 3-60 stimuli per minute), as well as the duration of the leading and trailing fronts of the envelope curve with amplitude modulation of the pulses from 0.3 to 8 sec.

The maximum value for the average current intensity with different kinds of stimuli is 25 mA with a 4000 ohm load on the output.

The apparatus is equipped with a protective relay which operates when the current in the patient's circuit goes above 50 mA.

The apparatus is powered from an alternating current source at a frequency of 50 Hz, and voltages of 127 or 220 V; voltage can vary from the nominal value by +5 to -10%. The power consumption is 60 VA.

The overall dimensions of the apparatus are 420 × 325 × 175 mm, and it weighs 12 kg.

The block diagram of the apparatus is shown in Figure 124.

The schematic diagram is in Figure 125. The instrument consists of three principal units. The first of these consists of the four rectifiers, one of which (No. 2) provides sinusoidal pulses of constant polarity, which form the basis of the pulses of therapeutic currents; the remaining three rectifiers serve as power supplies.

The second unit is the stimulus modulator, which produces all of the different forms of stimulus shapes listed above. The stimulus modulator in turn consists of a square-wave generator, a shaping stage, and a modulator in which the stimuli are given their final shape.

All the parts of the modulator are powered from rectifier No. 1. The third unit is the output amplifier stage, and the oscilloscope block connected with it; the latter includes a tube on whose screen the shape of the pulses of therapeutic current are observed; these are powered by rectifiers No. 3 and No. 4.

A study of the schematic diagram and operation of the apparatus should begin with the square wave generator which modulates the pulses of therapeutic current. This generator consists of a relaxation oscillator, using a MTX-90 tube (V_2) and a multivibrator,/142 consisting of two such tubes (V_3 and V_4). The MTX-90 tube is a thyratron with a cold cathode.

The voltage in the anode circuit of the relaxation oscillator (tube V_2) is obtained from the voltage divider consisting of resistors 10 and 11. [Potentiometer 10 is adjusted when the apparatus is taken apart to change tube V_1 (voltage stabilizer) or V_2, or to carry out some other adjustment of the apparatus]. Depending on the position of switch S_2, the circuit to the tube is formed either by resistors 12 and 13 or 14 and 21. When the voltage is applied, a charge passes from the reservoir capacitor 4, connected to the triggering electrode. When the voltage in the capacitor (and consequently, on the electrode) reaches a required value, the thyratron ignites. The internal resistance of this tube drops sharply and capacitor 4 discharges through the thyratron. The discharge current involves a considerable voltage drop across resistor 24 in the thyratron circuit, so that the voltage in the latter drops and the thyratron goes out. The process of charging capacitor 4 is then repeated, etc. The operating frequency of the relaxation oscillator is regulated by resistor 13 in the thyratron supply circuit.

Control of the operating regime of the apparatus, i.e., formation of certain pulses of stimulating current, is accomplished by means of switches S_1 and S_2. Switch S_1 is the main switch by which the shape of the therapeutic current pulses is produced; in the apparatus, it is called the "current-shaping switch", and has seven operating stages. Switch S_2 works in conjunction with it, and is called the "stimulus-shaping" switch, having only two positions: constant or alternating pulses.

In Regime I, (constant stimuli), the therapeutic current passes directly to the output amplifier (without modulation) in the first two steps. Accordingly, the relaxation oscillator is disconnected (see the first two positions on the first plate of switch S_1).

In the remaining five steps for operation in this regime (constant stimuli), the relaxation oscillator operates at frequencies of 60, 60, 10, 15 and 19 ignitions per minute, corresponding to a pulse period of 2, 2, 12, 8 and 7 sec. This involves a stepwise adjustment of resistors 14 and 21 on the first plate of the switch S_1.

In Regime II (alternating stimuli), the relaxation oscillator operates at a frequency which can be regulated smoothly from 6 to 120 pulses in 1 min, corresponding to the smooth adjustment of the dual resistor 13.

The voltage pulses from resistor 24 in the cathode circuit of the relaxation oscillator pass through separating capacitors 5 and 6 to the triggering electrodes of the multivibrator tube.

The multivibrator operates as follows. When the supply voltage passes through the contacts on the second plate of switch S_1 (the first two contacts are empty, and the multivibrator is open, i.e., transmission of therapeutic current is constant) and the anode resistor 7 in the multivibrator is set to a regime in which one of the tubes (e.g., the left) is ignited. The voltage drop in this tub tube decreases and that in the resistor 27, connected in the cathode circuit, increases; its potential becomes much greater than the cathode potential of the second tube, V_4. Capacitor 7 then charges. This multivibrator regime is stable and is retained until an igniting pulse from the relaxation oscillator reaches the triggering electrodes of both tubes and the second tube ignites. The voltage on the cathodes of both tubes is then equal and capacitor 7 discharges through resistor in the cathode of the first tube. This is accompanied by an additional voltage drop in this resistor; the voltage which reaches the tube drops below the extinction voltage /143 and tube V_3 goes out. The multivibrator changes to the second stable condition, from which it will be converted again to the former condition by another pulse from the relaxation oscillator.

The pulses from the multivibrator, recorded across resistor 28, have a rectangular shape, with a ratio of 1 to 1 between the duration and pause; they have a frequency equal to half the frequency of the pulses from the relaxation oscillator. (The amplitude is 60-70 V in amplitude value). The pulses from the multivibrators pass to the circuit of the intermediate shaping stage. This stage uses a 6N6P tube (V_5), whose triodes are used as two independent cathode repeaters, and contains electromagnetic relay R_1, whose contacts are used to control the charging and discharging of capacitor 9, thus smoothing (lengthening) the fronts of the modulating pulses.

Now let us move on to a consideration of the main section of the circuit. The pulses of therapeutic current are formed by rectification of the alternating current in tube 6X2P (V_7) which reach this tube from the winding of transformer Tr (terminals 9, 10, 11). In the case of two half-period rectification, the pulse frequency is 100 Hz, while with one half-period rectification it is 50 Hz, with a corresponding pause between pulses. The frequencies are switched on plate 5 of switch S_1.

The pulses reach the anode circuit of tube 6P15P (V_6), in which they are shaped in amplitude to fit the voltage supplied to the screen grid of this tube. The modulated pulses pass from resistor 32 in the cathode circuit of the tube in the grid of tube 6N6P (V_9) of the amplifier.

Capacitor 8, which is connected in parallel with resistor 32, gives the sloping portion of the sinusoidal pulses a smoother exponential shape.

Now let us follow the circuit for shaping the modulating pulses, which reach the screen grid of tube V_6. Rectangular pulses from the multivibrator consisting of tubes V_3 and V_4 pass through resistor 29 to the grid of the left-hand triode in tube V_5. In the cathode circuit of the triode, the winding of relay R_1 is connected in series with resistor 30. The relay contacts control the charging and discharging of capacitor 9, which is connected through resistor 35 to the grid of the right-hand triode in tube V_5. The voltage required for charging capacitor 9 is formed on the voltage divider consisting of resistors 56 and 58. The charging of capacitor 9 takes place through adjustable resistors: in Regime I, these are resistors 48-55, which are switched stepwise on the third plate of the switch S_1; in Regime II, it is resistor 47, which is continuously variable. These resistors are used to adjust the rise time of the leading front of the modulating pulses. Charging of the capacitor takes place through the upper contact of the relay (as shown in the diagram), taking place during the pause between pulses from the multivibrator. Smoothing of the wave front takes place as a result of the gradual rise in potential in the triode grid in the process of a gradual charging of capacitor 9. When completely charged, capacitor 9 supplies a positive potential to the grid of triode V_5.

A positive pulse from the multivibrator activates the relay so that a discharge from capacitor 9 passes through its lower contact and through certain resistors. In Regime I, these are resistors 40-46 (fourth plate of S_1), while in Regime II they are resistors 36 and 37 which are continuously variable. This regulates the duration of the trailing edge of the modulating pulses. When capacitor 9 discharges, the potential on the grid of triode V_5 drops; When the capacitor is completely discharged, the tube is closed by a negative potential on the grid, which reaches it through the same resistors.

The voltage pulses from resistor 34 in the cathode circuit of triode V_5 pass through resistor 33 (limiting current in the grid circuit) to the screen grid of tube V_6, which acts as a modulator. /144

The rounding off of the leading and trailing fronts of the modulating pulses, recorded across resistor 34, is also produced by resistor 38, connected in the cathode of the triode.

Hence, the transmission of therapeutic current pulses to the output amplifier takes place during the pause between pulses from the multivibrator, while in the continuous regime it takes place when the multivibrator is disconnected, and vice versa.

Short and long period currents (fourth and fifth stages of both regimes) are formed as follows: pulses of constant amplitude constitute half-periods of rectified current (in the two half-period circuit), and then pass through the contacts on the fifth plate of switch S_1 to the "output" resistor 32, passing only through resistor 31 and skipping all other elements of the circuit, i.e., in unmodulated form. The pulses which alternate with them in the signal, modulated in amplitude, are transmitted to resistor 32 via tube V_7. These pulses are combined into a common signal in resistor 32.

Output amplifier V_9 operates in a regime of independent negative bias on the grids (-18 V), supplied by a voltage divider consisting of resistors 39 and 72, connected to a rectified voltage of 400 V. The amplified voltage is obtained with a regulating potentiometer 75 and passes to the output terminals through a milliammeter with shunt 76 and polarity switch S_4.

From the output terminals, the voltage passes through a divider consisting of resistors 77 and 78 and through separating capacitors 15-16 to the deflecting plates 7-8 of cathode ray tube V_{10}.

On the cathode of the output amplifier (two triodes of which are connected in parallel with one another), there is a connection to the winding of protective relay R_2, which is shunted by capacitor 14 and resistor 74. The circuit of resistor 74 opens when the relay operates, thus increasing the current through the coil. The relay contacts thus short circuit the output potentiometer 75 and completely cut off the voltage from the patient's circuit. At the same time, other relay contacts supply "minus" to the grids of the amplifier tube V_9 and close it, and also close a circuit which shunts tube LNI, indicating that the relay is operating.

The power for the circuits to the relaxation oscillator, multivibrator, and tube in the shaping stage (V_2, V_3, V_4 and V_5) comes from a rectifier consisting of four semiconductor diodes D7Zh (D_1-D_4) in a push-pull circuit with doubled voltage on capacitors 1 and 2 and power from the transformer winding (terminals 4-5). The rectified and doubled voltage is filtered (resistor 8, capacitor 3) and

stabilized by stabilitron SG1P (V_1), with resistor 9 included in the circuit. The voltage at the filter output is 150 V.

The power from the output amplifier tube V_9 and the block of the oscilloscope tube comes from two combined rectifiers. One of them is made up of a full-cycle circuit with diodes D7Zh (D_5-D_{12}) with a ripple filter consisting of resistor 67 and capacitors 10 and 11. Terminals 8, 10, and 12 of the transformer are used. The rectified voltage is 300 V. The second rectifier has a one half-period circuit, using a selenium rectifier D_{13}, with a ripple filter consisting of resistor 71 and capacitors 12 and 13. Terminals 10 and 13 of the transformer are used. The output voltage is 400 V. The rectifiers are interconnected so that the output of the center tap of the winding serves as the plus for one rectifier and the minus for the other.

The oscilloscope block contains the ZL01I (V_{10}) tube, whose electrodes are powered by the voltage divider consisting of resistors 68-70 and the sawtooth voltage generator for scanning, consisting of thyratron V_8. /145

DETAILS OF SCHEMATIC DIAGRAM

Resistors

1	SV-0.5-27 Ω II	51	MLT-0.5-200 kΩ II
2-5	MLT-0.5-200 kΩ II	52	SPO-0.5-680 kΩ 5 mm
6	MLT-0.5-62 kΩ I	53	MLT-0.5-330 kΩ II
7	MLT-0.5-10 kΩ I	54	SPO-0.5-1 MΩ 5 mm
8	MLT-1.0-620 Ω I	55	MLT-0.5-390 kΩ I
9	MLT-2.0-3 kΩ I	56	MLT-1.0-39 kΩ I
10	SPO-0.5-68 kΩ 5 mm	57	SPO-0.5-18 kΩ 5 mm
11	MLT-0.5-82 kΩ II	58	MLT-0.5-18 kΩ I
12	MLT-0.5-470 kΩ II	59-66	MLT-0.5-200 kΩ II
13	SP-III-OS-3 20 gr. III In Series A 1 w 4.7 M ± 10% / A 2 w 4.7 M ± 10%	67	MLT-0.5-5.1 kΩ I
		68	SP-I-OS-3 20 gr. IV A 2 w 68 kΩ
14-16	MLT-0.5-2 MΩ II	69	SP-I-OS-3 20 gr. IV A 2 w 180 kΩ
15-17	SPO-0.5-2.7 MΩ 5 mm	70	MLT-0.5-0.56 MΩ I
18	MLT-0.5-3.3 MΩ II	71	MLT-0.5-20 kΩ I
19	SPO-0.5-4.7 MΩ 5 mm	72	MLT-1.0-10 MΩ I
20	MLT-0.5-300 kΩ II	73	MLT-0.5-47 kΩ I
21	SPO-0.5-1.0 MΩ 5 mm	74	Wire-wound PPZ-12-15 kΩ ± 5%
22	Wire-wound 5 Ω (PEK-0.25)	75	Wire-wound 8000 Ω ± 10%, 25 w
23	MLT-1.0-1.5 kΩ II	76	Wire-wound 2.3 ΩA (PEK-0.3) adjustable
24	MLT-0.5-5.1 kΩ I	77	MLT-0.5-0.62 MΩ I
25-26	KLM-1-33 MΩ I	78	MLT-0.5-1.0 MΩ I
27-28	MLT-0.5-100 kΩ I	79	MLT-1.0-6.2 MΩ I
29	MLT-0.5-0.51 MΩ I	80,81	MLT-1.0-10 MΩ I
30	MLT-0.5-30 kΩ I		
31	SPO-0.5-3.9 kΩ 5 mm		
32	ULI-1.0-39.8 kΩ ± 1%		
33	MLT-0.5-3.0 kΩ I		

34	MLT-0.5-47 kΩ I
35	MLT-0.5-0.51 MΩ I
36	MLT-0.5-200 kΩ II
37	SP-I-OS-3 20 gr. III A 2 w 4.7 MΩ ± 10%
38	MLT-1-6.2 kΩ I
39	MLT-0.5-0.51 MΩ I
40	MLT-0.5-47 kΩ I
41	MLT-0.5-0.82 MΩ II
42	SPO-0.5-1.5 MΩ 5 mm
43	MLT-0.5-200 kΩ II
44	SPO-0.5-390 kΩ 5 mm
45	MLT-0.5-390 kΩ I
46	SPO-0.5-1.0 MΩ 5 mm
47	SP-OS-3 20 gr. III A 2 w 4.7 MΩ ± 10%
48	MLT-0.5-200 kΩ II
49	MLT-0.5-47 kΩ I
50	SPO-0.5-390 kΩ 5 mm
81	MLT-1.0-10 MΩ I
82	SP-I-OS-3 20 gr. IV A 2 w 4.7 MΩ
83	MLT-1.0-6.8 MΩ I
84	MLT-1.0-10 MΩ I
85	SP-OS-3 20 gr. IV A 2 w 4.7 MΩ
86	MLT-1.0-6.8 MΩ I
87	MLT-1.0 10 MΩ I
88	SPO-0.5-39 kΩ 5 mm
89	MLT-0.5-10 kΩ I
90	MLT-0.5-120 kΩ I
91	MLT-1.0-6.2 MΩ I
92	MLT-0.5-0.51 MΩ I
93	MLT-0.5-2.2 MΩ I
94	SP-OS-3 20 gr. IV A 2 w 4.7 MΩ
95	MLT-0.5-1.5 MΩ I

Capacitors

1-3	KE-2-300-30 m
4	MBGO-2-400-2 II
5-6	KT-1a-M75-43 1-3 cathode
7	KBGI-400-0.015 I
8	MBGTs-2-1000 A-0.1 II
9	MBGO-2-400-1 II
10	KE-2-450-40 M
11	KE-2-400-5 M
12-13	MBGO-2-500-I II
14	KE-2-20-100 M
15-16	MBM-160-0.25 II
17	MBGO-2-300-1 II
18	KBGI-200-0.025 II
19	MBGP-2-400-A-0.25 I
20	KBGM-600-0.04 II
21	KBGI-600-0.01 II

Fuses

F_1	PM-20-0.5
F_1	PM-20-1.0
F_2	PK-45-0.15
F_3	PK-45-0.25

An overall view of the apparatus is shown in Figure 126, a. Figure 126, b shows the electrodes: (1) strip electrodes, (2) pointed electrodes with curved handles, and (3) pointed electrodes with a jointed handle. /146

The apparatus is mounted in a flat metal cabinet with a slighty sloping lid made of plastic, which serves as a control panel.

The following parts are mounted on the control panel (Fig. 126). At the upper left corner is the screen of the oscilloscope tube, covered by a magnifying lens (1); in the right-hand corner is milliammeter (5). Between them are the lenses of the thyratrons: in the middle is the relaxation amplifier (3), and on either side are the triodes of the multivibrator, 2 and 4. In the center of the panel is knob 11 for selecting the type of current. Below it are the lenses of the pilot lights: at the left is a white light (12) which indicates that the apparatus is plugged into the line; on

the right is a red light (10) which comes on when the protective relay is operating. On the left-hand side of the panel from top to bottom are the knobs for controlling the leading and trailing fronts of the pulse envelope (16 and 15, respectively), and knob 14 for regulating the pulse period, as well as knob 13 for selecting

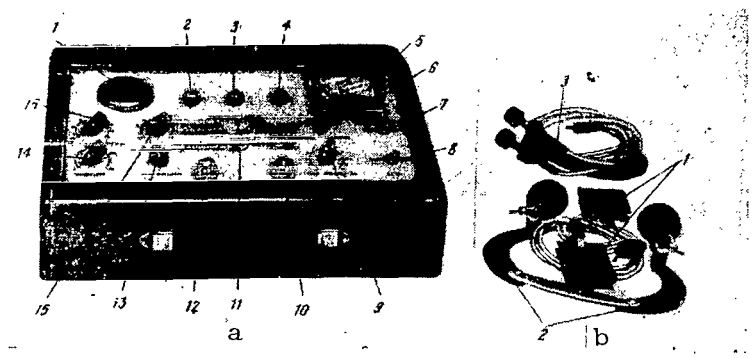


Fig. 126. Overall View of the SNIM-1 Apparatus (a) and the Electrodes (b).

the pulse type (continuously variable). On the right-hand side of the panel are the following: at the top, a polarity switch 6 and a switch 7 for selecting the range of adjustment of the current; on the bottom is knob 9 for adjusting the potentiometer (patient current) and line switch 8. The output terminals, as well as the contacts for connecting the apparatus to the line voltage are located on the back of the cabinet.

On the left-hand side of the apparatus is a line-voltage switch with a fuse, as well as a separate, removable cover which conceals five adjustment knobs for adjusting the image on the screen of the oscilloscope tube: "scanning frequency", "brightness", "focus", vertical" and "horizontal".

Figure 127 shows the apparatus as it looks when removed from the cabinet and with the front control panel removed. The electrical parts are mounted on a chassis and on the back of the control panel; power transformer 1 is located in the middle of the chassis. To the right of it is the cathode ray tube 2 and below it on the chassis is the unit for powering it; on the side wall are knobs 5 for adjusting the image. Near tube 2, we can see the thyratron 3 for scanning, and to the left of it knob 4 for adjusting the scanning amplitude. Behind tube 2 is stabilitron 6. To the left of the thyratron, there is a hole 7 for changing the fuses in the high-voltage part of the /147 apparatus, as well as a group of capacitors 8.

On either side there are vacuum tubes. On the right is the output tube 11 (V_9) and tube 12 of the shaping circuit (V_5); on the left is the converter modulator tube 9 (V_6) and the kenotron 10 (V_7); between these tubes is resistor 16 (marked 31 in the circuit). To the left and behind the tubes is a resistor (marked 74 on the circuit). Both resistors are beneath slits. Electromagnetic relay 13 can be seen in back.

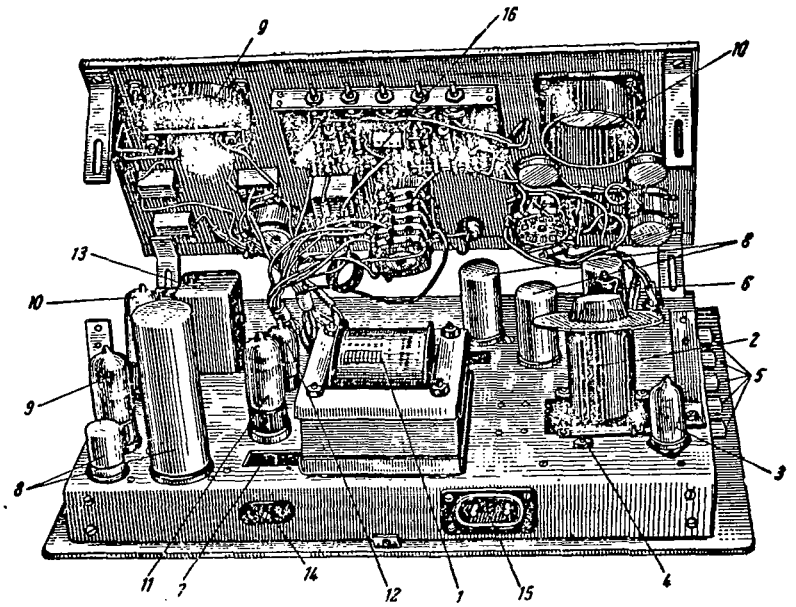


Fig. 127. Location of Parts in the SNIM-1 Apparatur.

At the front (in other words at the back of the chassis) are sockets 14 for connecting the electrodes and 15 for the line cord.

On the front of the chassis (not visible in the picture) there are seven openings, where the resistors marked 57, 54, 52, 50, 46, 44, and 42 in the diagram are located beneath slits.

On the back of the control panel are milliammeter 9, lens 10 of the oscilloscope tube, various switches, as well as the sockets for the three thyratrons in the relaxation amplifier and multivibrator. At the top, the resistors located behind the slits are mounted on a support; they are represented by 10, 15, 17, 19, and 21 in the circuit.

The equipment supplied with the apparatus includes the following:

1. The apparatus with all of the tubes required for operation (1 tube of each type).

2. Line cord, 2.4 m long. Wire for connecting the strip electrodes, 2.5 m long with clamps. Wire for connecting the circular electrodes, 2.5 m long.

3. Supply of spare lead strips for making electrodes: 4 × 5, 6 × 10 and 10 × 15 cm^2. Cloths for use with electrodes (10 pieces). Rubber straps (2).

4. Supply of spare circular electrodes, 24 and 49 mm in diameter.

5. Holder for hinged electrodes (1). Holder for bent electrodes (1).

6. Special wrench (1).

7. Spare parts: (a) fuses (4); (b) MTX-90 thyratrons (2); (c) vacuum tubes: 6N6P, 6GIP, 6P15P, TG-I-0.02/05, one each; (d) oscilloscope tube 3L01I (1); (e) adjustable potentiometer (8 kΩ).

The apparatus is assembled as follows to perform treatment. /148
Before connecting the apparatus to the line, it is necessary to check that all of the fuses are set for the line voltage to which the apparatus is to be connected, ensuring that all of the line switches are in the off position and the current-regulating knobs for the patient's circuit are in the zero position. The line cord is then connected to the apparatus, plugging the connector into the socket and the other end into the socket on the wall; the white pilot light should then light up. After allowing the apparatus to heat up for 1-2 min, it is ready for use.

The oscilloscope section must now be tested. To do this, the knob for selecting the type of current is set to the first or second position (constant current); the pulse switch knob is then set to the "constant" position, and the knob for regulating the patient's current is set to the third or fourth position, after which the polarity switch is set to the "direct" position. The oscilloscope tube should then display on its screen the image of a sine wave, whose quality can be adjusted by using the set of knobs on the side of the apparatus. After adjustment is complete, the knob of the current regulating system must be turned to the zero position.

When beginning treatment, the proper electrodes are selected and applied to the portion of the body to be treated by means of clamps and rubber strips (the cloths beneath the electrodes are moistened as in other methods of electrotherapeutics). The electrodes are connected to the wires which are then plugged into the socket on the back of the apparatus. The knobs of the corresponding switches are then set to the desired form of current (knob 11), the pulse shape (knob 13) and the polarity of the electrodes (knob 5).

If the procedure is to be carried out with "alternating" pulses, then before the wire is connected from the electrodes to the apparatus it is necessary to adjust the device for the desired pulse period and the distance between the fronts of the envelope. To do this, the polarity switch is set to the "direct" position and the current regulator knob is set to the third or fourth position; this causes an image of the current curve to appear on the screen, which can then be adjusted by moving the proper knobs to set the distance between the leading and trailing fronts of the envelope. The pulse period is adjusted by knob 14 and checked "by eye" for the frequency of the flashes visible in the lenses above thyratrons 2, 3, and 4 on the control panel. The knob of the regulator is then returned to the zero position and the electrodes are connected to the apparatus.

Once the desired type of current and pulse shape have been established, knob 9 is used to adjust the current in the electrode circuit while observing the patient and looking at the milliammeter on the control panel. If there is any need to change the type of current, electrode polarity or limits of the milliammeter scale during the treatment, knob 9 (which regulates the current in the patient's circuit) must first be returned to the zero position.

The instructions for using the apparatus are not unusual. However, when replacing the stabilitron (V_1), relaxation amplifier (V_2) and modulator tubes (V_6), and also if the instructions for use require that the duration and period of the pulses differ markedly from the nominal values, it is necessary to adapt the apparatus in a special manner in accordance with the instructions provided with it.

§ 7. APPARATUS FOR ELECTRONARCOSIS

The first instruments for electronarcosis were built at the State Institute of Physical Therapy and were manufactured in small numbers by the experimental machine shop of the Institute. These instruments were intended for simultaneously treating four patients /149 with independent adjustment of frequency and current intensity for each patient. The instruments were connected to a device for measuring the amplitude values of the current in the patient's circuit, which took the form of an oscilloscope tube without any time markings.

Later on, an apparatus for electronarcosis was also built by NIIEKhAiI. The apparatus was intended for simultaneously treating two to seven patients, with a common regulation of frequency for all the patients. The instrument was fitted with a cathode-ray oscilloscope for observing the shape and magnitude of the voltage pulses at the output terminals. Instruments of similar type were prepared by the Experimental Department of NIIEKhAiI.

In 1955, NIIEKhAiI devised a portable apparatus for electronarcosis for treating one patient, and this instrument has been produced by the Union Factory of the EMA since 1958.

The apparatus consists of a generator of voltage pulses of constant polarity and rectangular shape (the rise time for the pulse front does not exceed 100 μsec).

The pulse frequency is regulatable within a range of 2 to 130 Hz. The pulse duration changes as a function of frequency from 0.4 to 2 msec (at a frequency from 2 to 25 Hz, the pulse duration is from 2 to 1 msec, while at a frequency from 25 to 130 Hz it is 1 to 0.4 msec).

The maximum output voltage with a load resistor of 5000 ohms is 20 + 5 V in amplitude value of the pulses.

The apparatus makes it possible to obtain a pulsed voltage with a constant component superimposed on it; the latter is regulated within 0 to 20% of the pulse amplitude, and there is also a device for measuring the resistance across the output terminals of the apparatus.

The apparatus is powered by current from the power line at 127 or 220 V, and does not draw more than 40 VA. The presence of electronic stabilizers makes it possible to keep the voltage required for normal operation of the apparatus stable, with variations in line voltage between -15 to +5% of the nominal value.

The schematic diagram of the apparatus is shown in Figure 128. The pulse generator consists of a multivibrator with self-excitation, a limiter, and an output tube, which has the form of a cathode repeater. The entire circuit consists of two bantam tubes (dual triodes) 6N1P. The first tube V_1 serves as the multivibrator. The pulse frequency is regulated stepwise by switching capacitors 1-5 in one of the arms of the multivibrator; adjustments are also possible within each stage by adjusting potentiometer 21, which changes the value of the bias applied to the multivibrator grid.

The left-hand half of the second tube V_2 serves as a limiter, which provides pulses of a strictly square wave type. The pulses pass from the limiter through capacitor 5 to the grid of the right-hand half of tube V_2, which serves as a cathode repeater. The cathode circuit of the repeater contains an output regulating potentiometer, 19.

The generator portion is fitted with a dual shielded circuit for the patient, to protect him from considerable current increases in case there should be any difficulty with normal operation of the apparatus. Neon lamp MN-3 (L_7) is connected in parallel with potentiometer 19; this lamp ignites and shunts the potentiometer when the amplitude values of the voltage pulses in the potentiometer are higher than the permissible value. The voltage in the potentiometer then drops sharply. The anode circuit of the output tube contains an electromagnetic relay R connected in parallel with resistor 10; this relay disconnects the tube circuit when it operates.

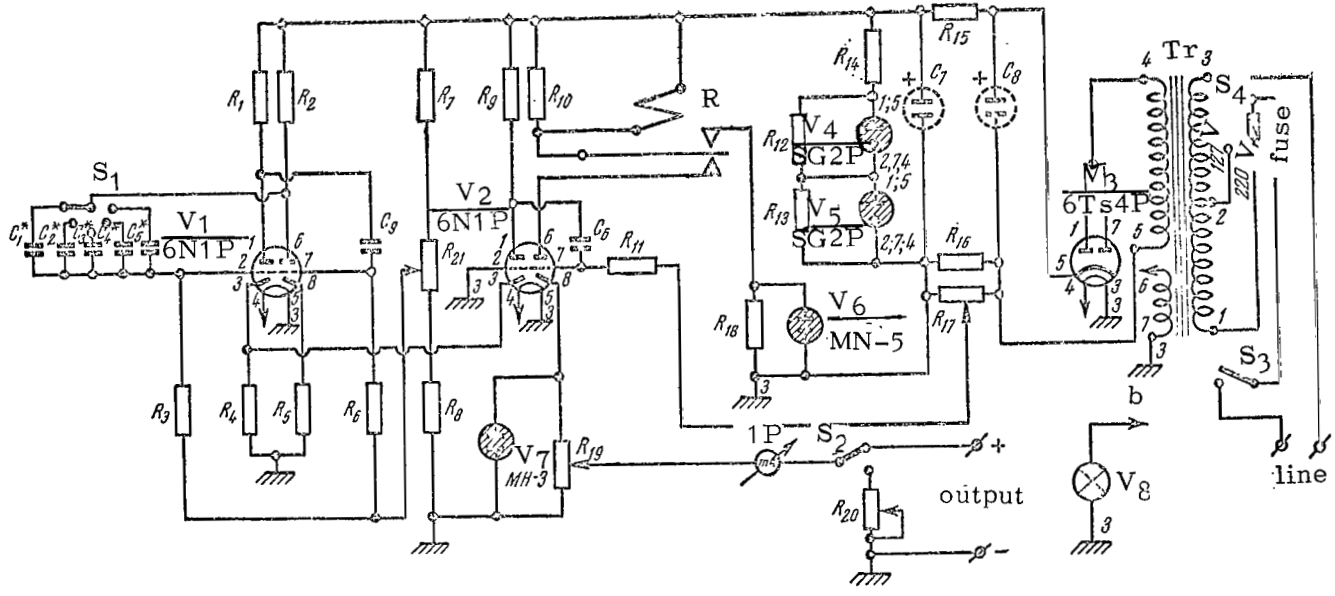


Fig. 128. Schematic Diagram of Apparatus for Electronarcosis, as Manufactured by the EMA Factory.

This occurs if the average current value in this circuit exceeds the established value. Neon pilot light MN-5 (L_6) also lights up at this time, its lens is located on the control panel. /151

The generator portion of the apparatus is followed by a transformer Tr which feeds through a single half-period rectifier using a kenotron 6Ts4P (V_3) with a filter (resistor 15 and capacitors 7 and 8) and two stabilitrons SG-2P (V_4 and V_5). Potentiometer 17 is connected to the minus lead of the rectifier, and is used to provide a constant bias to the grid of the output triode, in order to produce a constant component for the pulsed voltage.

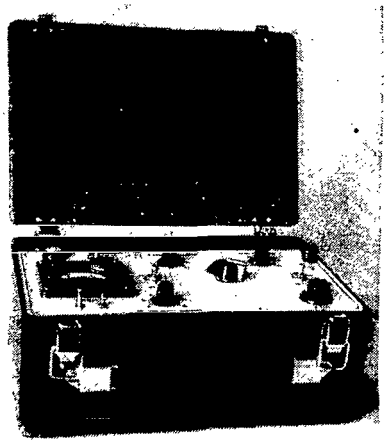


Fig. 129. Overall View of Apparatus for Electronarcosis as Produced by the EMA Factory.

By means of switch S_2, regulating resistor 20 can be connected to the output of the apparatus. If the reading of the milliammeter on the control panel is observed during treatment, resistor 20 is connected to the output after treatment is complete, and we then adjust its value to obtain the same readings, the value of resistor 20 will be equal to the resistance of the patient's circuit during the treatment. This resistance consists of the sum of the resistances of the patient's skin, located in the circuit between the electrodes, and the resistances in the contacts between the electrodes and the patient's skin. The latter depends to a considerable extent upon the quality of the surface contact, the amount of moisture on the electrodes and their proximity to the skin, so that the measurement is very approximate.

The following are the data on the resistors and capacitors:

Resistors

1-2	MLT-1 39 kΩ ± 10%	12-13	MLT-1 100 kΩ ± 10%
3	MLT-0.5 10 MΩ ± 10%	14	MLT-2 1 kΩ ± 10%
4	MLT-1 8.2 kΩ ± 10%	15	MLT-2 3.9 kΩ ± 10%
5	MLT-1 3 kΩ ± 10%	16	MLT-2 330Ω ± 10%
6	MLT-0.5 1 MΩ ± 10%	17	SP-II-2a-22A
7	MLT-0.5 510 kΩ ± 10%	18	MLT-2 10 kΩ ± 10%
8	MLT-0.5 100 kΩ ± 10%	19	SP-II-2a-6.8A-12L
9	MLT-1 33 kΩ ± 10%	20	SP-I-2a 15A-13L
10	MLT-1 3.6 kΩ ± 10%	21	SP-I-2a 470A-13L
11	MLT-1 1.5 MΩ ± 10%		

Capacitors

1	KSO-2 500 V 470 nf ± 10%	6	KBGI 200 V 0.1 μf ± 10%
2	KSO-2 500 V 1200 nf ± 10%	7	KZ-2 400 V 20 μf ± 10%
3	KSO-5 250 V 2500 nf ± 10%	8	KZ-2 400 V 10 μf ± 10%
4	KSO-5 500 V 5100 nf ± 10%	9	KSO-2 500 V 1000 nf ± 10%
5	KBGI 200 V 0.05 μf ± 10%		

An overall view of the apparatus is shown in Figure 129. It /152
is mounted in a plastic carrying case, ich has a compartment in the bottom for storing the line cord ana the electrodes. The overall dimensions of the carrying case are 285 × 206 × 135 mm; it weighs approximately 6 kg.

On the left-hand side of the control panel is the milliammeter, below which are the lenses of the pilot lights (at the left is lamp No. 9 which indicates that the apparatus is switched on, while lamp

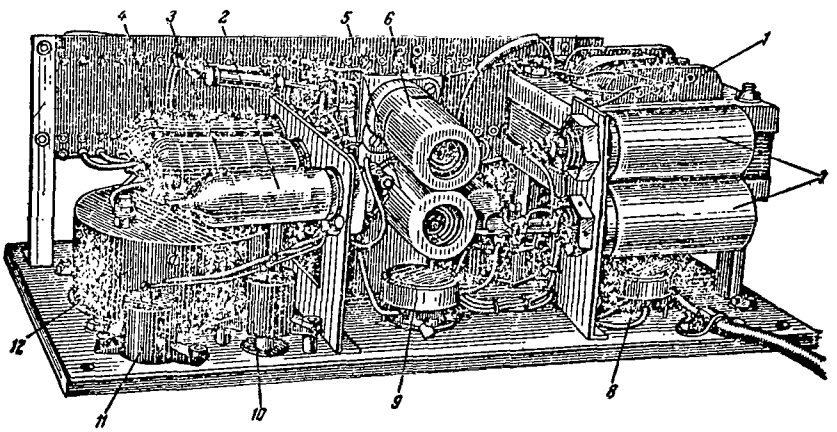


Fig. 130. Location of Components in the Apparatus for Electronarcosis as Manufactured by the EMA Factory.

10 on the right shows that the relay is operating); below this are the sockets to receive the wires from the electrodes. On the right-hand side of the apparatus is knob 1 of the regulating potentiometer, and above it, switch 2 and knob 3 for the rheostat used to measure the circuit resistance between the electrodes. At the center and somewhat to the right is knob 4 for the stepwise regulation of frequency; at the right is knob 5 for the smooth regulation of frequency, line switch 6 and fuse 7, which also serves for changing the input voltage from 127 to 220 V or vice-versa (8 is the grounding terminal).

There is an opening on the front of the carrying case through which the potentiometer determining the value of the constant component can be adjusted.

All the parts are mounted on the back of the front panel. An overall view of the panel is shown in Figure 130.

At the right is transformer 1 and near it are filter capacitors 7; in the middle are the two tubes 5 and 6 (6N1P) of the generator section, while at the left are kenotron 2 and stabilitrons 3 and 4. Milliammeter 12 is located directly on the same control panel, as are sockets 11 and 10 for the pilot lights and potentiometers 9 (for measuring the resistance between the electrodes) and 8 (for the smooth regulation of frequency).

Fig. 131. Attachment of Electrodes for Electronarcosis on Patient.

Performing the treatment in /153 electronarcosis requires use of specially designed electrodes which are applied to the eyelids (minus) and to the region of the mammiform appendages behind the ears (plus). The electrodes consist of flat plastic cups, filled with physiological solution, and lids made of stainless steel, sealed with a wad of moistened cotton. Electrodes are fastened to the points mentioned above by rubber straps, worn like a helmet on the head (Fig. 131).

PART 0

THERAPEUTIC APPARATUS USING CONSTANT ELECTRICAL FIELD AND ATMOSPHERIC IONS

§ 1. GENERAL CONSIDERATIONS

An electrical field is a form of matter which can be used to promote connection and interaction of electrical charges. The principal feature of an electrical field is the force acting on the charges located in the field. A field associated with charges which are invariable in value and position is called a constant electrical field. Later on we shall be talking about an alternating electrical field, which is made up of charges whose sign varies and which is at the same time a component part of a more complex electromagnetic field.

The principal value which characterizes an electrical field is the field intensity E, a vector quantity equal to the force which the field exerts on a unit positive charge located at a given point

in the field. An electrical field can be represented graphically by a system of lines of force or intensity, i.e., the images of the lines to which the vectors of the field intensity are tangent at any point.

The lines of force run from a positive charge to a negative charge, and the number of lines in 1 cm^2 perpendicular to its surface is directly proportional to the field intensity. The appearance of the distribution of the lines of intensity in space between the charges depends on the shape and the mutual positions of the surfaces (electrodes) at which the charges are located. In particular, if these surfaces are metal, the lines of force will run perpendicular to them.

The intensity of an electrical field between two flat, parallel electrodes of equal area is numerically equal to the ratio of the potential difference (voltage) U, applied to the electrodes, to the distance d between them:

$$E = \frac{U}{d} \text{ V/cm.}$$

If some medium is located between the plates of a charged capacitor, the electrical field will act on the charges located in this medium. A real dielectric will contain both linked as well as free charges. The free charges, moving about under the influence of the electrical field along the lines of force, will form a "conductivity current". The lower the quality of the dialectric, the greater will be the conductivity current produced in it. Under the influence of the electrical field, linked charges will be shifted somewhat relative to their mutual position along the lines of force, /154 causing polarization of the dielectric. Such a shifting of charges is called the shift current in the dielectric.

In some materials (water, many hydrocarbons, etc.), the molecules are polar in structure. Such molecules are called dipoles. In the absence of an external field, thermal motion causes the polar molecules to arrange themselves in the mass of the material with no particular order, so that the average value of the electrical field inside the material is equal to zero (Fig. 132, a). If such a dielectric be placed in an electrical field, the polar molecules will be affected by a force which tends to align the molecules so that their poles are located along the lines of force of the field (Fig. 132, b). This phenomenon is called orientational polarization of a dielectric.

If the molecules have free mobility, which is characteristic only for gases, they will arrange themselves along the lines of force of the field. If the molecules do not possess free mobility, then the action of the field will only cause them to move somewhat out of their original positions, so that the material will enter a certain charged state. In particular, e.g., the action of a sufficiently strong electrical current can change the struc-

ture of complex polar molecules.

The ability of a substance to be polarized in an electrical field is characterized by a value called its dielectric constant. Usually this value is expressed relative to air, whose dielectric constant is taken as equal to 1.0. The greater the dielectric constant, the higher the degree of polarization of the dielectric under given conditions.

The relative dielectric constants of some materials are listed in Table 14.

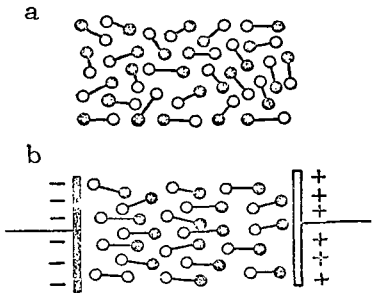


Fig. 132. Schematic Representation of Orientation of Polar Molecules in an Electrical Field.

TABLE 14

Air	1.0
Paraffin	2.0
Glass	from 6 to 10
Amber	12
Water	81

In several materials (Rochelle salt, barium titanate, etc.), the dielectric constant reaches several thousand.

Pure, dry air is a dielectric. In nature, however, air always contains a small amount of free electrons and ions which are formed under the influence of various external factors such as the action of ultraviolet solar radiation or radioactive radiation from materials located in the Earth's crust, cosmic rays, etc.

Electrons and gas ions in the air are usually formed in conjunction with gas molecules or their groupings and form complex ions called atmospheric ions.

Atmospheric ions can be divided into three classes on the basis of their size (mass): light, medium, and heavy (Table 15).

TABLE 15 /155

Type of Ion	Radius (cm)	Mobility ($cm^2/V \cdot sec$)
Light	$7 + 10 \cdot 10^{-8}$	7 - 2
Medium	$80 + 250 \cdot 10^{-8}$	0.01 - 0.001
Heavy	$250 + 550 \cdot 10^{-8}$	0.001 - 0.00025

The light atmospheric ions are distinguished by their high mobility and instability; they recombine rapidly.

Heavy atmospheric ions are formed by the precipitation of light atmospheric ions on fine droplets of water vapor, dust particles, etc., suspended in the air. Heavy atmospheric ions are less mobile and more stable.

If an electrical field is formed in air, the ions and electrons located in it will move toward the electrodes, forming an electrical current of insignificant value. In the presence of a sufficiently strong field, the ions are accelerated sufficiently so that when they strike neutral molecules the latter are split, thus ionizing the gas further. This process is called secondary ionization or shock ionization. In shock ionization, the current through the gas increases, accompanied by various light and sound phenomena.

With a relatively low ionization intensity in the air, there is a so-called quiet discharge, accompanied by the formation of a current of ions and air molecules between the electrodes, called the electric breeze. At a somewhat higher intensity, the quiet discharge is accompanied by a characteristic crackling or hissing, as well as by the formation of ozone in the air (in darkness, a slight glowing of the surfaces between which the charge is located can also be observed). A quiet discharge appears first at irregularities or projections located on the charged surfaces, since at these points the field intensity is greater and there is a more intense ionization of the air. At still greater ionization intensities, the quiet discharge can turn to a spark discharge.

§2. FRANKLINIZATION AND ATMOSPHERIC IONIZATION

The use of a constant electrical field of high intensity to produce therapeutic affects on patients can be achieved by means of a static shower, or franklinization. Franklinization can be applied either as a general or local treatment.

In general, the following method is the one most often used (Fig. 133). The patient sits on a chair, with his feet on a metal sheet 2, connected to one of the poles of a source of high voltage. The metal sheet and chair are mounted on an insulated stand 3. At a distance of 12-15 cm above the patient's head is an electrode 1; it is hemispherical in shape and of small size, perforated with holes and connected to the second pole of the high voltage source. The treatment varies depending on the polarity of the electrode; the upper electrode is usually connected to the positive pole.

Because the upper electrode is perforated by holes in which there is a higher field intensity, a quiet electrical discharge is produced which passes over the subject in the form of a light "electric breeze".

During the treatment, the patient is in contact with one of the electrodes, connected to the voltage source, and separated from the second (head) electrode by a large air gap, in which most of the voltage applied to the electrodes is dissipated. Therefore, the intensity of the electrical field within the patient's body is relatively low. The intensity of the polarization and the conducting current intensity in the tissues of the organism are correspondingly low. /156

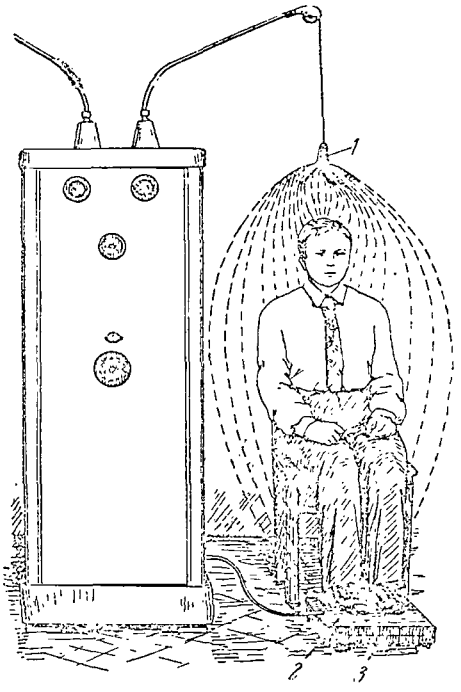


Fig. 133. Diagram of Treatment by General Franklinization.

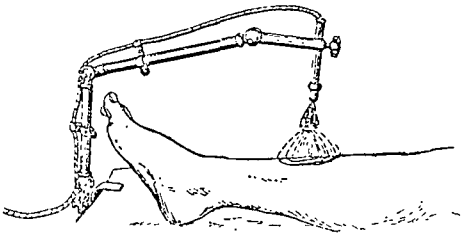


Fig. 134. Diagram of Method of Applying Local Franklinization.

The quiet electrical discharge which passes between the head electrode and the surface of the shoulders, neck, head and face of the patient is of particular importance, as are the static electric discharges on these surfaces. The flux of atmospheric ions reaching the surface of the skin is absorbed and has a stimulating effect on the nerve receptors located beneath the skin; in addition, the absorbed ions can produce certain electrochemical reactions in the skin. The inspiration of ionized air by the patient undergoing the treatment is also of importance.

In the case of local treatment (Fig. 134), the active electrode either takes the form of a hemisphere of smaller diameter (also perforated by holes), or the shape of a small brush, ball, or point.

The electrode is connected to one terminal of the apparatus and placed several centimeters away from the surface of the body. The second electrode is not used. Depending on the magnitude of the voltage on the electrode (relative to ground), as well as the distance from the surface of the body, an electrical discharge

will be formed between the electrode and the body which differs in intensity from an electric breeze to a mild spark.

The apparatus used for franklinization must provide a high voltage (up to several tens of kilovolts), of constant sign, with a very small current intensity (on the order of milliamperes), compensating for the charge leakage between the electrodes.

The breathing of atmospheric ions is often used as a separate procedure both in treatment of certain diseases as well as in strengthening the organism by increasing its tonus and resistive powers. Light atmospheric ions are generally used for therapeutic and prophylactic purposes, and usually have one sign (usually negative).

A great many physical phenomena are used to produce atmospheric /157
ions in significant numbers: (a) a quiet electrical discharge, (b) highly disperse atomization, (c) the effect of radioactive radiation on air. It is also possible to use other phenomena for this purpose, such as the action of ultraviolet radiation on air, etc.

In all of these phenomena, there is an intense formation of atmospheric ions of both signs. The ions of one sign are then absorbed somehow in the apparatus while the ions of the other sign are emitted into the atmosphere surrounding the apparatus, where they are used for therapeutic purposes. Atmospheric-ion therapy and especially atmospheric-ion prophylaxis are used not only for individuals by means of small machines but also for group treatments by means of special installations.

§3. AF-2 APPARATUS FOR FRANKLINIZATION

The first instruments for franklinization, which used high alternating voltage rectified by means of an X-ray kenotron, were built at the State Institute of Physical Therapy. The machines were similar to the type produced by the EMA Factory (No. AF-1), had a single half-cycle circuit for rectification, and were distinguished by the high percentage of voltage pulsations (despite the use of ripple filters). The instruments were intended only for general treatment. Later on, the factory improved the design of the instrument, using a full-cycle circuit for rectification and equipping it for local treatment as well; a voltage regulator was built into the apparatus at the same time. This version was first made in 1958 as No. AF-2.

The AF-2 apparatus is intended for general treatment of two patients simultaneously or for local treatment of one patient. The nominal data of the apparatus are as follows:

1. Maximum voltage at the electrodes of the apparatus is 50 kv. The voltage pulsations do not exceed 10%. Voltage can be regulated in stages (5 kv each).

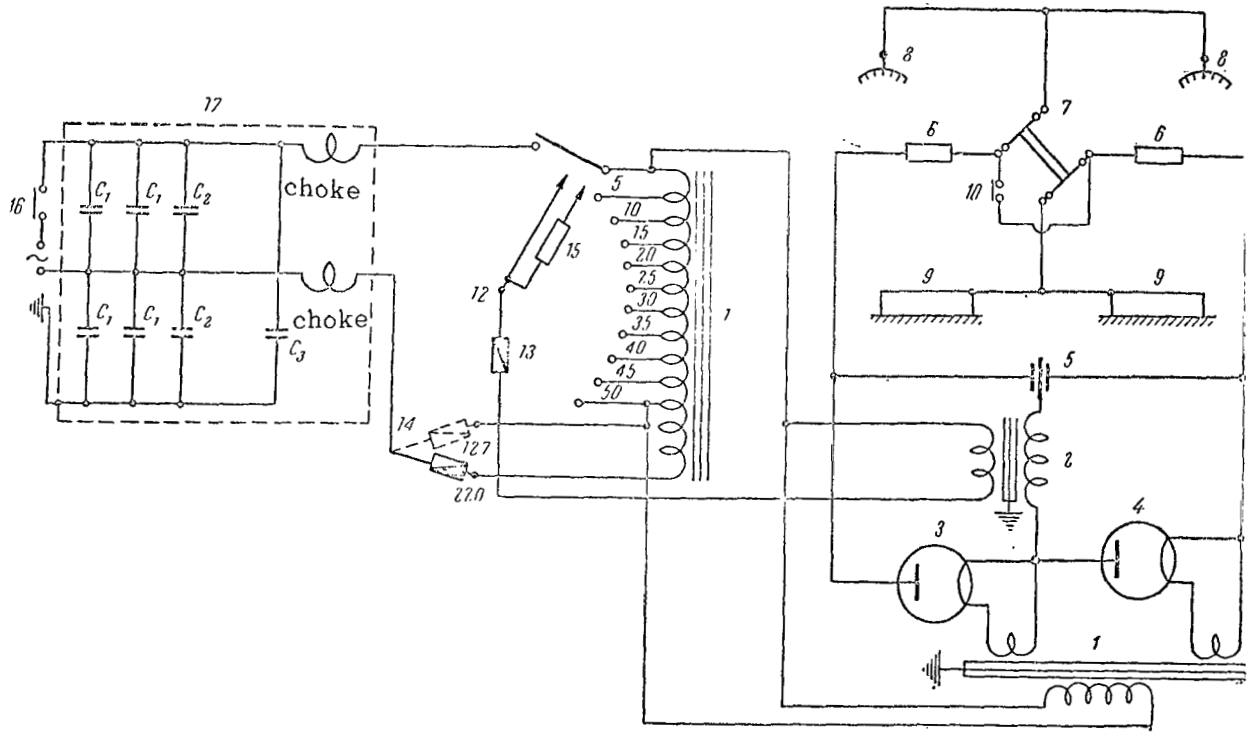


Fig. 135. Schematic Diagram of AF-2 Apparatus for Franklinization.

2. The short-circuit current at the output terminals does not exceed 500 μA.

3. The power which the apparatus draws from the power line is about 500 volt-amperes (the current at a line voltage of 127 V is 4 A, and it is 2.2 A at 220 V).

4. The overall dimensions of the apparatus are 1530 × 565 × 475 mm (the height including the arms for supporting the electrodes is 2140 mm). It weighs approximately 60 kg.

The schematic diagram of the apparatus is shown in Figure 135. The high voltage, with fixed sign, is obtained by means of a high voltage transformer in a dual circuit. Two circuits are connected in parallel with the secondary winding of transformer 2, each of them consisting of an X-ray kenotron, type KR-110 (marked 3 and 4 in the circuit), and one-half of a dual capacitor 5. The filament wires of the kenotrons are powered by a separate transformer 1. This portion of the circuit is a full-cycle high-voltage rectifier with a voltage doubler. In each of the half cycles of the voltage in the stepup winding of transformer 2, a current passes through the corresponding kenotron and charges half of the capacitor to a voltage close to the amplitude value of the voltage in the stepup winding.

Both halves of the capacitor are connected in series, so that their voltages are added.

The effective value of the voltage in the stepup winding of the transformer is 21 kv, which corresponds to an amplitude value of approximately 30 kv. As a result of the doubling in capacitor 5, the voltage which reaches the electrodes is about 55 kv without a load and about 50 kv during treatment. This voltage reaches the electrodes through protective resistors 6, which limit the value of the current in case of a short circuit between the electrodes of the apparatus, and switch 7 for adjusting the polarity of the electrodes. From the polarity switch, the voltage passes to the head and leg electrodes (8 and 9, respectively). A discharger 10 is connected between the contacts of opposite polarity in switch 7. The discharger is in the form of a knife switch whose blade is held in the open position by the back cover of the instrument cabinet when it is in place. When this back cover is opened, the blade falls under the force of gravity and immediately short-circuits the contacts of switch 7. /159

To regulate the voltage, which is especially important in the case of local treatment, a regulating autotransformer 10 is included in the primary circuit of the high-voltage transformer 2. The autotransformer has 10 steps, permitting regulation of high-voltage in 5 kv steps. Knob 12 on the switch for connecting the terminals of the autotransformer connects the power supply to the autotransformer in the initial position. The contacts of the switch overlap

the adjacent terminals of the autotransformer; a resistor 15 serves to limit the current in the short-circuited turns.

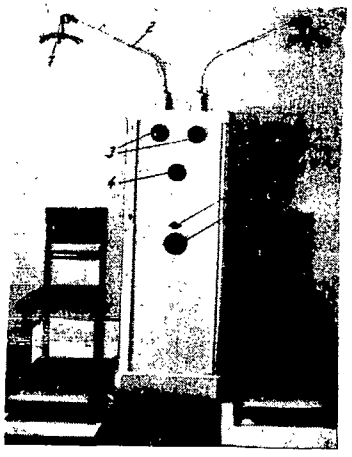


Fig. 136. General View of AF-2 Apparatus.

A fuse 13 is located in the circuit of the high voltage transformer. A second fuse 14 is connected to the circuit of the autotransformer and serves simultaneously for switching the line voltage between 127 and 220 V.

The line-cord circuit contains filter 17 for suppressing radio interference; this filter consists of two high-frequency coils and a group of capacitors C_1-C_3 connected in parallel. Three wires run from the filter to the socket: two line-cord wires and a third for grounding. It is necessary to ground the apparatus. The instrument is plugged into the wall socket by means of a special three-wire plug provided by the manufacturer. For technical data on the parts of the apparatus, see the Second Edition of this book.

A general view of the apparatus is shown in Figure 136; it is mounted in a cabinet with wooden sides. Porcelain insulators are mounted on the top, supporting metal rods which carry the head electrodes 1.

The following are mounted on the front of the cabinet: at the top are knobs 3 for controlling the mechanism which raises and lowers the head electrodes; below them is knob 4 for the polarity switch and below that are pilot light 6 and knob 5 of the voltage regulator switch. On the sides of the cabinet, at the bottom, are the sockets for connecting the wires from the leg electrodes.

Figure 137 shows an overall view of the location of the parts within the apparatus (the view shows the back of the cabinet).

On the right-hand side are contacts 10 for the door interlock, /160 while a the bottom is a socket for plugging in the line cord.

At the bottom of the apparatus is an oil tank 1 containing the high voltage transformer, the filament transformer, and the dual voltage capacitor. In the center of the tank lid is an opening for checking the level of the oil; this opening is sealed with a plug. There are also four upright insulators; two of them support kenotrons 2 and the others carry the wires to the protective resis-

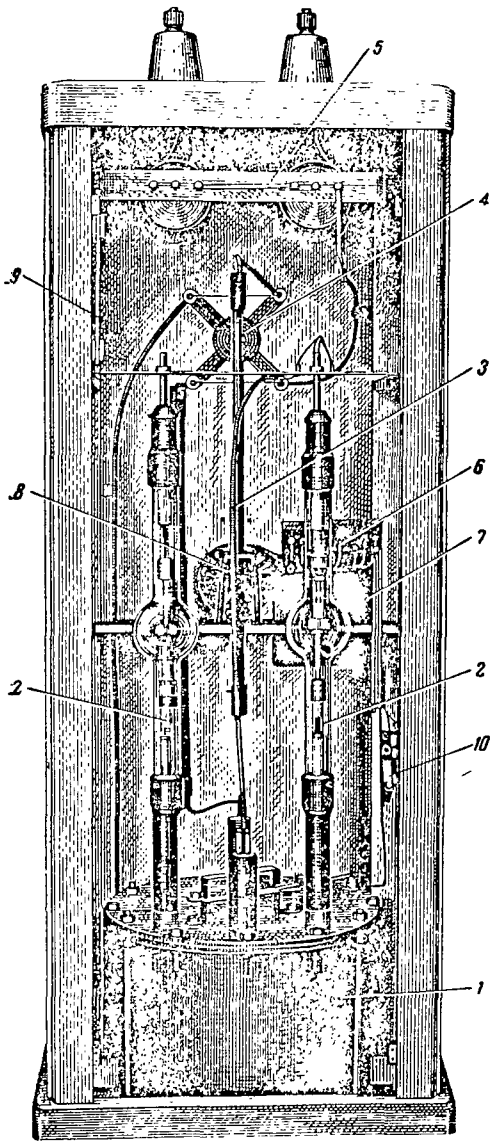


Fig. 137. Internal View of AF-2 Apparatus.

tors which are mounted in a vertical position within Bakelite tubes.

In the center of the front panel is autotransformer 7 and a cover 6 with leads.

At the left is switch 8 for the autotransformer terminals.

The upper section contains switch 4 for controlling polarity, while above this on the sides are two drums 5 on which are wound the cables which support the head electrodes; on the left side is discharger 9.

The following equipment is supplied with the apparatus:

1. Oil bath with high voltage transformers (shipped separately from the apparatus) - 1.

2. Kenotron KR-110 (spare) - 3.

3. Head electrode for general franklinization - 2.

4. Support for foot electrode - 2.

5. Socket for electrode used in local franklinization - 1.

6. Electrode for local franklinization - 3.

7. Wire, 2 m long, with high voltage insulation for local treatment - 1.

8. Wire for foot electrode - 2.

9. Line cord, 2.5 m long - 1.

10. Special socket - 1.

11. Wrench - 1.

12. Fuses PK-2 a and PK-4 a - 1 each.

13. Technical description, instructions and certificate.

The apparatus is used as follows for giving treatment. Before beginning treatment, raise the head electrode all of the way; seat the patient on the chair so that his feet are located on the metal plate of the lower electrode. /161 The foot electrode is then connected to the apparatus. The shoes and socks are usually removed. The patient is instructed to remove all metal objects from his pockets: pocketwatch, keys, etc. He must also remove any buckles that he may be wearing, and take off his wristwatch. Women should take hairpins out of their hair, etc., since charges will accumulate on all such objects and form high potentials which could lead to a formation of a spark discharge. For this reason, the patient must not be touched during the treatment; he must remain seated in a comfortable posture and must remain absolutely still.

The polarity switch is then set to the desired position for the treatment. The polarity of the electrodes must never be changed while the apparatus is switched on.

If the treatment is being given to two patients simultaneously, both of them must be treated with the electrode polarity exactly the same and with approximately the same distance between their heads and the head electrodes. The two of them must be prepared for the treatment and seated before the apparatus is switched on.

After making the above-described preparations for treatment, the apparatus can be switched on; by turning the knob to regulate the voltage, the latter can be set to the required level.

When turning on the apparatus, a characteristic noise is heard (a soft crackling sound), which is typical of a quiet discharge. It will be noticed mainly around the openings in the head electrode, and the patient will feel a light breeze coming from the head electrode.

When treatment is complete, the apparatus must first be switched off and the head electrode raised out of the way. Only then should the patient be allowed to get out of the chair.

No metal objects of any kind (especially grounded ones) should be anywhere near the patient during treatment.

When performing local treatment, it is necessary to unplug the apparatus from the wall, unscrew the head electrode from the base and replace it by the plug of the wire leading to the local electrode. Then, after placing the patient in a comfortable position for receiving treatment, the support for the electrode holder is clamped to the edge of a stool, couch, or bed; the proper electrode is then inserted in it (brush, point, or ball).

After placing the electrode in the required position relative to the patient, the apparatus is switched on and the voltage is set to the value required. The leg electrode is not used in local franklinization.

The high capacity of the capacitors used in this apparatus means that they retain the charge for a long time. Therefore, it is necessary to wait 15 or 20 sec before touching the metal parts of the apparatus which are charged during operation after unplugging the apparatus; this period is required for the capacitors to discharge (through leakage). This must be taken into account when changing electrodes in general or local treatment.

It is suggested that before changing the electrodes, the capacitors should be discharged by touching the head and leg electrodes with a wire having high voltage insulation.

§4. APPARATUS FOR FRANKLINIZATION AND ATMOSPHERIC IONIZATION, AF-3

In 1958, the EMA Factory devised a new type of apparatus for franklinization (AF-3), in which a high voltage of constant sign is obtained by rectification and then amplification of a lower alternating, high-frequency voltage which is specially produced in the /162
apparatus for this purpose. This makes it possible to do away with the need for a high-voltage transformer in the apparatus, which was frequently a source of trouble in the AF-2.

The AF-3 apparatus is intended for performing both general and local franklinization on one patient, a group of patients individually, or for local atmospheric ionization. The nominal data of the apparatus are as follows:

1. The maximum working voltage is 50 kv. The changes in the working voltage with variations in the line voltage within limits of +5 to -10% does not amount to more than ± 12%. Voltage pulsations do not exceed 1%. The voltage can be regulated in 5 ± 1 kv steps.

2. The short-circuit current at the output of the apparatus does not exceed 400 a.

3. The power drawn from the line is 150 voltamperes at the maximum.

4. The overall dimensions are 370 × 565 × 665 mm; the apparatus weighs 26 kg.

The block diagram of the AF-3 apparatus is shown in Figure 138; the schematic diagram appears in Figure 139. The apparatus consists of three main components: (a) the high-frequency generator[1]

---

[1] Since the basis of the electrical circuit of the AF-3 apparatus is a high-frequency generator, it is first recommended that the reader acquaint himself with the contents of Part 2 in Chapter IV.

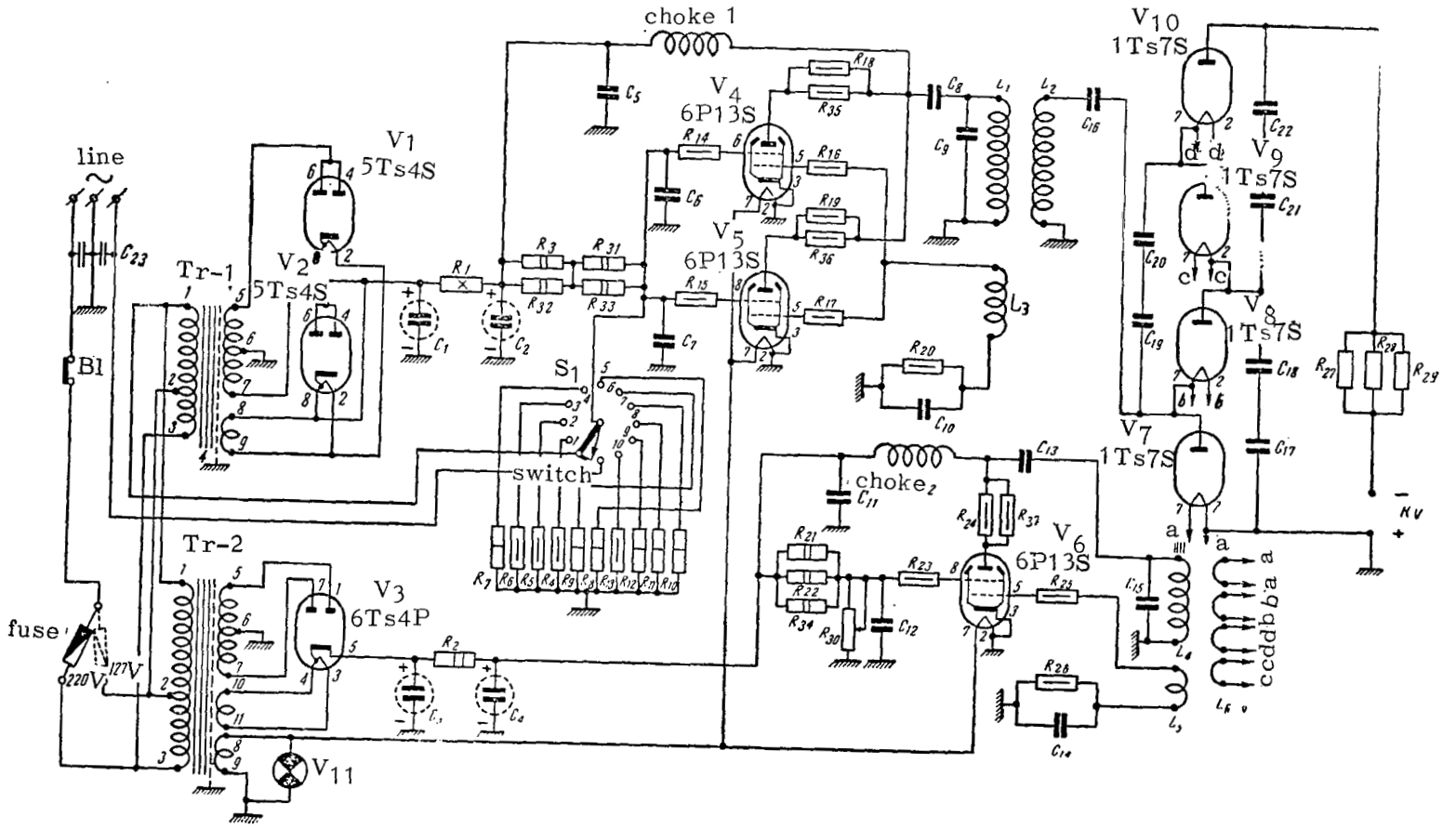


Fig. 139. Schematic Diagram of AF-3 Apparatus.

which provides the working voltage, with a power supply unit; (b) an auxiliary high-frequency generator for powering the tube filaments, also with its own power supply, and (c) a high voltage rectifier and multiplier for the operating voltage.

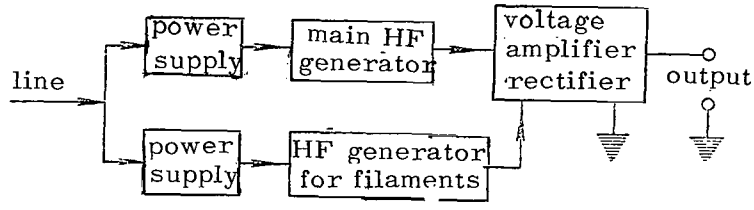


Fig. 138. Block Diagram of Apparatus Used for Franklinization and Atmospheric Ionization, AF-3.

The basic generator with an operating frequency of 54 KHz is based on a one-stage circuit with two beam tetrodes 6P13S (V_4 and V_5), connected in parallel, with an oscillating output (inductance L_1 and capacitance C_3) in the anode circuit, with inductive feedback, produced by means of coil 3 and automatic bias of the grid current (resistor 20 shunted by capacitor 10). The resistors in the anode (18, 34, 19, 36) and grid (16, 17) circuits are antiparasitic and serve to damp out any oscillations in the generator which differ in frequency from the nominal value. The anode circuit of the generator is powered by a parallel circuit with the blocking elements; these are a choke 1, shunted by capacitor 5 and separating capacitor 8.

The output voltage of the generator is regulated by changing the voltage on the screen grids of the tubes by means of a divider consisting of a set of resistors 3, 31, 32 and 33 and resistors 4 to 13, which are connected by means of switch S_1. In the zero position, switch S_1 disconnects the circuit of the primary winding of the power transformers. Resistors 14 and 15, shunted by capacitors 6 and 7 at high frequencies, are connected to the grid circuit. /164

The auxiliary generator for powering the filaments also uses a 6P13S tube (V_6) and a similar circuit. The operating frequency of the generator is 140 kHz. The generator load is a circuit formed by the filament wires in the four kenotrons of the amplifier, inductively connected to coil L_4 of the oscillator circuit by means of coils L_6-L_9. The filament voltage is 1.3 V.

The high-frequency voltage from the oscillator section of the main generator is passed by induction to coil L_2 of the amplifier, thus increasing to 15 kv at peak value.

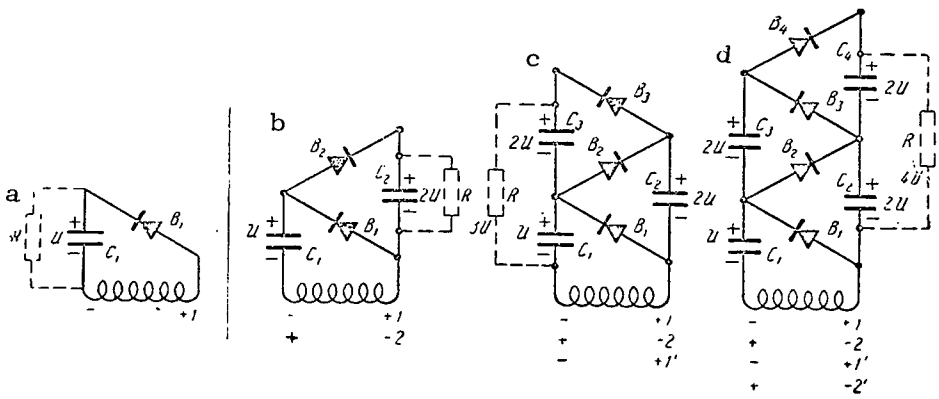


Fig. 140. Schematic Diagram of Voltage Amplifier.

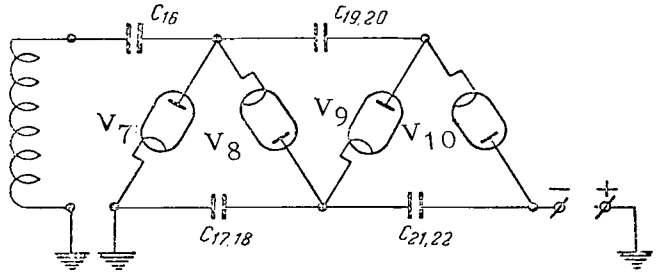


Fig. 141. Schematic Diagram of Voltage Amplifier in AF-3 Apparatus.

The schematic diagram of the voltage amplifier in the AF-3 apparatus is shown in Figure 141. The amplifier consists of a single half-period rectifier with quadrupling of the voltage. The operating principle is shown in Figure 140. In Figure 140 a, we can see a diagram of the single half-period rectifier in which the voltage U rectified by rectifier B_1 passes to capacitor C_1 to which load R is connected. In Figure 140 b, we see the diagram of the voltage doubler. During the first half cycle, the current in the circuit travels as shown in Figure 156 a. Capacitor 1 is then charged to voltage U. During the second half cycle, the current passes through capacitor 1, rectifier 32 and capacitor 2. The transformer voltage is then added to the voltage stored in the capacitor 1 during the first half cycle, so that the capacitor 2 is charged to twice the voltage 2U with a polarity on the plates as indicated in the diagram. A load is connected to capacitor 2. /165

In Figure 140 b, the amplifier in which capacitor 1 is charged to voltage U and capacitor 2 is charged to voltage 2U, is equipped

with a rectifier B_3 and a capacitor 3. During the next half cycle, the current in the circuit passes through capacitor 2, rectifier B_3 and capacitors 3 and 1. The voltage from the transformer is then added to the voltage from capacitor 2, but the voltage in capacitor 1 is subtracted from the sum. As a result, capacitor 3 charges to voltage 2U with the polarity of the plates as shown in the figure. The load is connected to the capacitors 1 and 3. The voltage in it amounts to 3U (voltage tripling circuit).

By adding rectifier B_4 and capacitor 4 (Fig. 140, d) and proceeding in the same way (half cycle 2), we can see that capacitor 4 is also charged to twice the voltage, 2U. The load connected to capacitors 4 and 2 will then be at voltage 4U. This means that the voltage is quadrupled.

The voltage amplifier in the AF-3 apparatus (Fig. 141) consists of four high-voltage kenotrons 1Ts7S (V_7-V_{10}) and seven high-voltage capacitors 16-22 at a working voltage of 15 kv each. The amplifier produces a voltage of 50 kv. Protective resistors are connected in series at the output of the amplifier (a special high-voltage type for a working voltage of 35 kv), and serve to limit the current in the circuit in the case of a short circuit at the output, which could happen, e.g., if the patient should touch both electrodes at the same time.

A peculiar feature of this circuit is that the positive potential from the amplifier goes to the lower electrode while the head electrode is connected to the chassis of the apparatus which serves as the negative pole in the circuit.

The rectifiers which power the generators use 5Ts4S kenotrons in a full-cycle circuit and have ripple filters at the output (resistors 1 and 2 and capacitors 1-2 and 3-4); the rectifier for the main generator has two kenotrons, whose anodes are connected in parallel.

The supply wires pass through the interlock on the back of the cabinet and the dual noise-suppressing capacitor 23. The apparatus must be grounded.

Details of Schematic Diagram

Resistors

1	PEV-30-750 ohms ± 5%	11	ULI-1-10 kohms ± 1%
2	MLT-2-680 ohms ± 5%	12	ULI-1-15 kohms ± 1%
3	MLT-2-30 kohms ± 1%	13	ULI-1-27 kohms ± 1%
4	ULI-0.5-1.2 kohms ±1%	14-17	MLT-0.5-300 ohms ± 10%
5	ULI-0.5-1.8 kohms ± 1%	18&19	VS-0.5-56 ohms ± 5%
6	ULI-0.5-2.4 kohms ± 1%	20	MLT0.5-15 kohms ± 10%
7	ULI-1-3.6 kohms ± 1%	21&22	MLT-2-91 kohms ± 5%
8	ULI-1-4.7 kohms ± 1%	23	MLT-0.5-300 ohms ± 10%
9	ULI-1-6.2 kohms ± 1%	24	VS-0.5-56 ohms ± 5%
10	ULI-1-8.2 kohms ± 1%	25	MLT-0.5-300 ohms ± 10%

26	MLT-0.5-20 kohms ± 10%	31-33	MLT-2-30 kohms ± 5%
27&28	KLV-3.5-150 Mohms	34	MLT-2-91 kohms ± 5%
30	SP-P-2-10 kohms ± 1%	35-37	VS-0.5-56 ohms ± 5%

Capacitors

/166

1 & 2	KE-2-500-20-M	11	MBGO-2-400-1 ± 10%
3 & 4	KE-2-400-20-M	12	KBG-I-200-0.05 ± 10%
5	MBGO-2-500-1 ± 10%	13	MBGTs-2-400-A-0.1 ± 10%
6 & 7	KBG-I-400-0.05 ± 10%	14	KBG-I-200-0.025 ± 10%
8	MBGTs-2-600-A-0.1 ± 10%	15	KTK-1000-8000 pf ± 2%
9	KTK-1000-26,000 pf ± 2% (consists of 26 units)	16 - 22	(consists of 8 units) KOB-2-20-500
10	KBG-I-200-0.025 ± 10%	23	KBG-MP-3H-600-2 x 0.1

Inductance Coils

1	143 microhenries
2	220 millihenries
3	7 turns
4	168 microhenries
5	9 turns
6 - 9	1 turn
Dr_1 - Dr_2	3 millihenries

Fig. 142. General View of AF-3 Apparatus.

The following is a general description of the apparatus as shown in the illustration in Figure 142; the internal components (as seen with the back of the cabinet removed) are shown in Figure 143. The apparatus is mounted on a wooden base 1; the front of the cabinet is fitted with knob 2 for adjusting the voltage, and lens 5 of the pilot light. On the right-hand side is a support 4 for the head electrode 3 and a clamp for plugging in the wire from the latter. The lead for connecting the leg electrode is plugged into the lower part of the back of the cabinet (see Fig. 143). In instruments of more recent manufacture, the leg electrode is not attached to the apparatus.

In the upper part of the back of the cabinet (Fig. 143) there is a high voltage cable 12 for connecting to the head electrode. In the lower part is a socket 1 for connecting the prongs of the line cord and a switch 2 for the line voltage, including a fuse.

The parts of the electrical section of the apparatus are divided between three areas in the cabinet. In the lower most section is the power supply: power transformers 1, kenotrons 5, filter capacitors 4, etc. The middle section contains the high-frequency generators; at the left is the main generator (7 is the induction coil for the oscillator circuit), while at the right is a generator for the filament voltage (6 capacitors; 8, induction coils for oscillator circuit and coils for powering the tube filaments). The uppermost section contains the high-frequency amplifier; kenotrons 9, capacitors 10, and the safety resistors contained in a Bakelite tube at the left 11.

The apparatus is supplied with the following: /167

1. Apparatus ready for operation with a complete set of tubes.
2. Support for head electrodes (1).
3. Electrodes: head, for general franklinization, spherical for group atmospheric ionization, flat for local atmospheric ionization, elongated for local atmospheric ionization.
4. Support for local franklinization, with spherical electrode and wire.
5. Line cord, 2.5 m long (1).
6. Special socket (three-pronged) (1).
7. Spare parts: fuses PK-45-1 (1); PK45-2 (1); vacuum tubes: 1Ts7S (4); 6P13S (3); 6Ts4P (1); 5Ts4S (1); pilot light: 13.5 V, 0.18 A (1).
8. Wrench (1).
9. Discharging handle (1).
10. Technical description, instructions, and certificate.

§5. APPARATUS FOR ATMOSPHERIC IONIZATION THERAPY AND ATMOSPHERIC IONIZATION PROPHYLAXIS

We will limit ourselves to a consideration of only those instruments which are referred to as electroeffluvial atmospheric ionizers, i.e., instruments in which the quiet electric discharge is used.

An example of such an atmospheric ionizer is the AF-3 franklinization apparatus. Measurements have shown that when this apparatus is operating, the number of negative light atmospheric ions at the level of the patient's head reaches 500-600 thousand per cm^3. /168

An example of a group atmospheric ionizer is the machine represented schematically in Figure 144, devised by A. L. Chizhevskiy. The apparatus consists of a so-called electroeffluvial chandelier, suspended from the ceiling in a location where atmospheric ionization is employed for therapeutic or prophylactic purposes, and a power supply which provides the high voltage required.

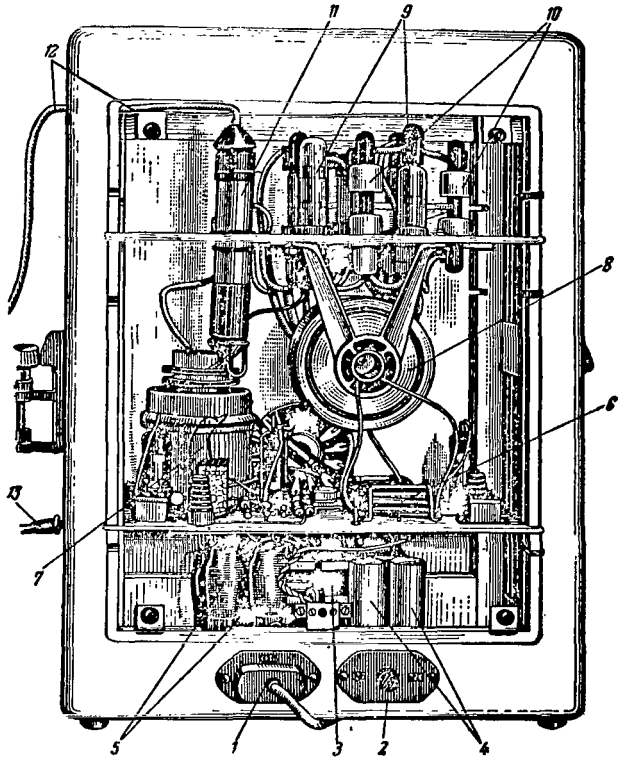


Fig. 143. Location of Parts in AF-3 Apparatus.

As shown schematically in Figure 144, the chandelier consists of a circular metal screen about 1 m in diameter, fitted with a number of points directed downward. One pole of a voltage source (usually the negative one), supplies 30 to 100 kv to the screen 1 through a limiting (protective) resistor 2. The second pole of the source is grounded. Above the screen is a fan 10, which forms a current of air which moves downward.

Under the influence of the high voltage, a quiet discharge is formed at the tips of the points on the screen, thus producing a large number of ions of both signs in the air. The positive ions /169
are attracted to the screen and neutralized. The negative ions are repelled from the screen and are carried downward in the current of air from the fan.

The power source for the chandelier is a high-voltage rectifier, consisting of a high-voltage transformer 4, a high-voltage (X-ray) kenotron 3, an autotransformer 5 for regulating the voltage, and a transformer 6 for heating the kenotron. The power circuit contains a fuse 8 and a switch 7.

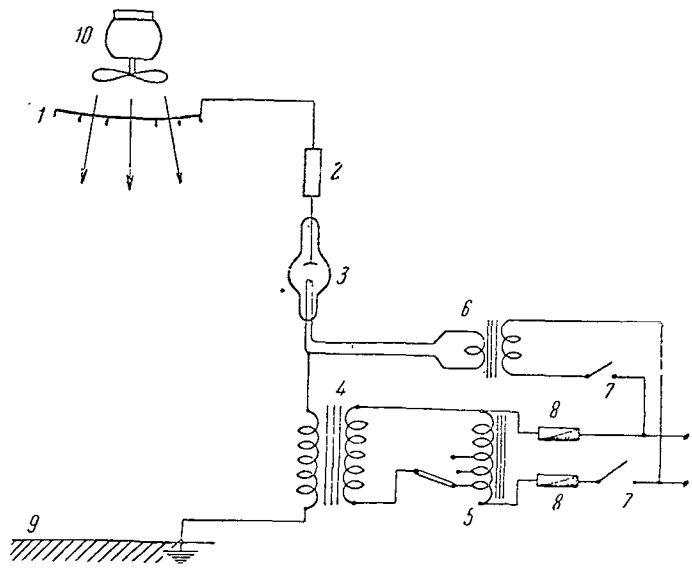


Fig. 144. Schematic Diagram of Group Atmospheric Ionizer.

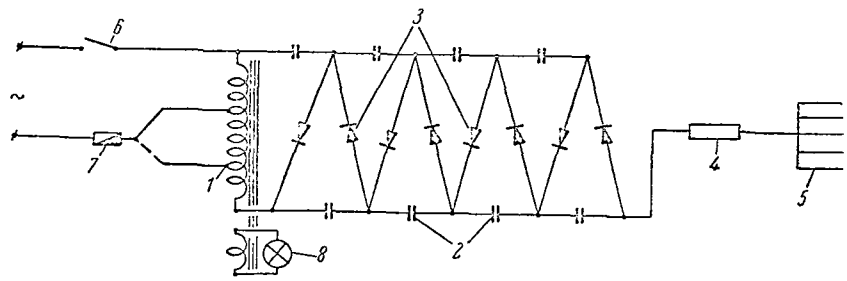


Fig. 145. Schematic Diagram of Individual Atmospheric Ionizer.

A similar apparatus is used to produce a concentration of light atmospheric ions, up to 10^6 ions/cm^3 at a distance of 1 m from the screen. A drawback of this installation is the fact that its operation produces small amounts of undesirable toxic elements (ozone and nitric oxide).

As an example of an individual table-model atmospheric ionizer, we can use the apparatus devised at the State Institute of Balneology and Physical Therapy. The schematic diagram of the apparatus (Fig. 145) consists of an autotransformer 1, powered by an octuple voltage amplifier, consisting of capacitors 2 and selenium rectifiers 3. The amplified voltage passes through limiting resistors 4 to the circular electrode 5, which has five points on it. The auto-

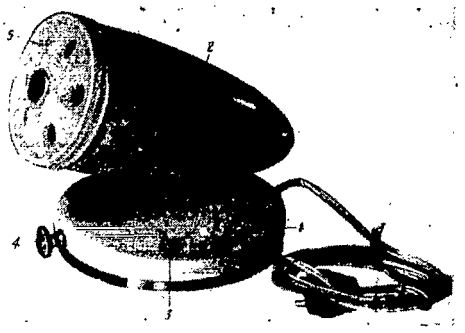


Fig. 146. Overall View of Individual Atmospheric Ionizer.

transformer is connected to the line by switch 6 and fuse 7. The autotransformer supplies a voltage of 375 V. A voltage on the order of 3.5 kv is supplied to the electrode.

Specifications of Circuit Components

1. Autotransformer.
2. Capacitors KBG-MP 2 x 0.05 μf, voltage equals 1000 V.
3. Selenium rectifiers AVS-5-1A.
4. Resistance VS-0.5; 10 MΩ.
5. Conical points (electrodes).
6. Switch.
7. Fuse (0.15 A).
8. Heating lamp 3.5 V, 0.28 V.

A general view of the ionizer is shown in Figure 146. The apparatus consists of a flat base 1 and an inclined body 2, which contains the principal electrical components. The base is fitted with button 3 for controlling the line voltage and head 4 of a screw which can /170 be used to adjust the angle of the body. Within the base, between the bottom and the upper part, there is a passageway for the line cord, containing the switch and the fuse. The body 2 is closed in front by a plastic cover 5 with five openings to allow the ion flux to emerge. The electrical components of the apparatus are mounted in a single unit (Fig. 147), which can be removed from the body after removing cover 5 and loosening two mounting screws. (When removing this unit from the body, it is necessary to be very careful so that the electrodes protruding at the front are not damaged). The unit consists of a transformer 1, beside which are located the selenium rectifiers 2 and capacitors 3 which form the amplifier circuit. On the other side is a mounting panel 4 and on the other a ring electrode 6 with points 7, around which the ion flux is formed.

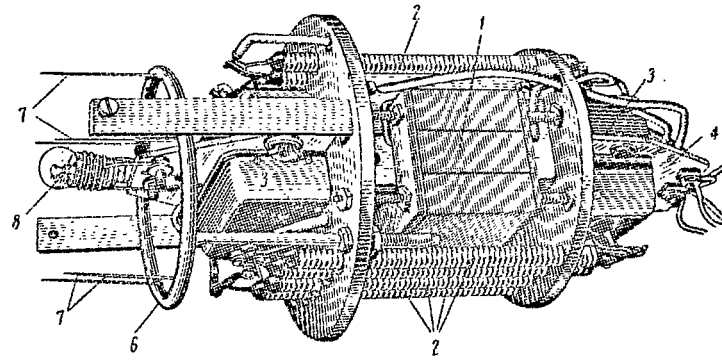


Fig. 147. Location of Parts in Individual Atmospheric Ionizer.

The limiting resistance is mounted near the points of the ring electrode. In the center of the electrode is a lamp 8 which indicates when the apparatus is plugged into the line.

The overall dimensions of this instrument are 240 x 177 x 155 mm; it weighs 1.8 kg.

CHAPTER IV

ELECTROTHERAPEUTIC APPARATUS USING HIGH-FREQUENCY CURRENTS

PART 1

PHYSICAL PRINCIPLES AND METHODOLOGY OF HIGH-FREQUENCY THERAPY

§1. GENERAL CONSIDERATIONS

Therapeutic methods of treating the organism with alternating high-frequency current or magnetic, electrical or electromagnetic fields differ rather substantially, but they are all linked by a general principle of design based on a generator of electrical oscillations. The principal differentiating factor is the oscillation frequency, as well as the means of treating the patient, which involve a system of electrodes. /171

The most important part of a generator of electrical oscillations is the oscillator circuit (see below, Part 2 § 1), where there is a process in which the electrical field of a capacitor is changed into a magnetic field of a coil and vice versa, at a certain repetition frequency. The combination of these fields forms an electromagnetic field called the induction field. Specifically, the induction field represents a shift by $\pi/2$ between the oscillation phases of the electrical and magnetic fields, as well as a link between the electrical field in the capacitor and the magnetic field in the coil. The method of using the electrical field from a capacitor, connected in the oscillating circuit of a generator of ultrahigh frequencies, to treat the tissue of an organism is called UHF therapy for short.

The method in which the tissue of the organism is subjected to the magnetic field from a solenoid connected to the oscillator circuit of a high-frequency generator is called inductothermy.

Under certain conditions, an electromagnetic induction field can also be formed in the solenoid. The total effect of such a field on the organism in a pulsed regime is called general d'arsonvalization.

The mutual interchange between the electrical and magnetic fields in the oscillator circuit forms a high-frequency current. The action of the high-frequency current passing directly through the tissue of an organism is called diathermy.

The effect of a discharge formed between the surface of the body and a glass electrode filled with rarefied air when a weak high-frequency current in a pulsed regime is passed through the latter, is called local d'arsonvalization.

The frequency of the electric oscillations depends on the capacitance and inductance of the circuit; when the latter decrease, the frequency increases. In the case of ultrasonic and supersonic frequencies, the capacitance and inductance, arranged along a straight wire, are sufficient to produce electrical oscillations in the latter. A circuit of this type is called an open oscillator circuit or a linear vibrator. In this case, the electromagnetic field is formed directly in the space surrounding the conductor, which itself forms an open oscillator circuit. This field is propagated in all directions by electroinduction in the surrounding space, and is called the radiation field. /172

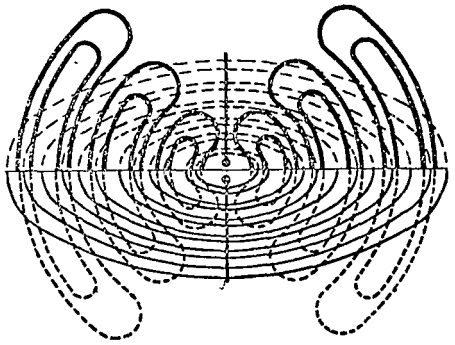


Fig. 148. Schematic Representation of Lines of Force in an Electromagnetic Field.

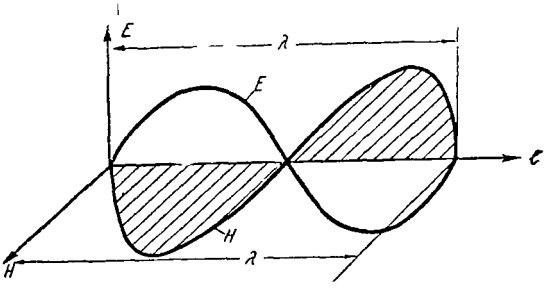


Fig. 149. Graph of an Electromagnetic Wave.

A radiation field is characterized by the fact that the oscillations of the electrical and magnetic components of the field are in phase, so that the electrical and magnetic fields cannot be separate in space as was the case in an induction field. Propagating into the surrounding medium in all directions, the electromagnetic radiation field forms an electromagnetic wave (with a specially designed vibrator, or when using special reflectors, the electromagnetic wave can be propaagated in the direction of the conductor).

It should be mentioned that a radiation field is also formed in a closed oscillator circuit, but its potential is very low;

as in an open oscillator circuit, there is an induction field, but only in the immediate vicinity of the conductor itself.

The electromagnetic field may be represented graphically by means of a system of lines of force. Figure 148 shows a schematic representation of the arrangement of the lines of force around the linear vibrator. The lines of the electric component of the field have the shape of flattened loops and are located in the meridional planes of a sphere; the lines of the magnetic component of the field have the shape of concentric circles, located in planes which are perpendicular to the meridional plane (in Fig. 148, only the electrical lines are shown which lie in the plane of the diagram, and the magnetic lines, lying in the equatorial plane of the sphere in the center of which the linear vibrator is located. For the sake of simplicity, the lines are partially represented by dots.

An electromagnetic wave can be represented by a graph representing the change in the vectors of the intensity in the electrical (E) and magnetic (H) field components, formed along the propagation direction of the wave (Fig. 149). In accordance with the spatial distribution of the vectors, the graph is plotted in two coordinate planes. /173

The electrical oscillations, as well as the electromagnetic waves produced by them, are characterized primarily by frequency oscillations which largely govern their effect on the tissue of an organism. In addition, the electromagnetic waves can be characterized by the wavelength, which in turn depends on the oscillation frequency.

Let us recall that the wavelength λ is related to the oscillation frequency ν and the propagation rate of a wave c is given by the formula:

$$\lambda\nu = c,$$

where λ is expressed in cm, ν is expressed in Hz, and c (in air) is equal to 3×10^{10} cm/sec.

In the region of high and ultrahigh frequencies, the frequency is usually expressed in mega Hertz (MHz), and the wavelength is expressed in meters (m); the formula then can easily be written in the following form, which is easy to remember:

$$\lambda\nu = 300.$$

From this we obtain:

$$\nu = \frac{300}{\lambda} \text{ MHz}$$

or

$$\lambda = \frac{300}{\nu} \text{ m}.$$

In accordance with this relationship, the wavelength is frequently employed as an oscillation characteristic for the corresponding frequency, particularly in several of the methods mentioned. In diathermy, e.g., in which electrical oscillations are used which have a frequency which corresponds to medium waves (see below), is called mediumwave diathermy, while inductothermy, in which oscillations of much higher frequency are used, is called shortwave diathermy. These terms should be avoided, since they could give rise to erroneous conclusions regarding the nature of the phenomenon, and one might think that electromagnetic waves were acting directly on the tissue of the organism in these methods, which is not the case in reality.

Depending on the frequency of their oscillations or their wavelength, electromagnetic waves can be divided into a number of ranges. Waves with a length from 10 km to 1 mm are called radiowaves. According to the International Standard (GOST 7768), the folowing names have been applied to the different ranges of radiowaves (Table 16).

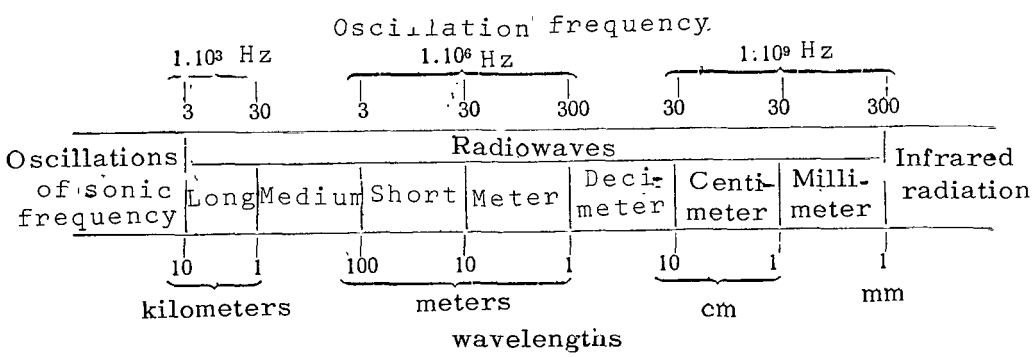
TABLE 16

Frequency	Wavelength	Name
100 kHz and less	3000 m and more	Long waves
100-1500 kHz	3000 - 200 m	Medium waves
1500-1600 kHz	200 - 50 m	Intermediate waves
6-30 MHz	50 - 10 m	Short waves
30-300 MHz	10 - 1 m	Ultra-short waves: Meter
300-3000 MHz	1 - 0.1 m	Ultra-short waves: Decimeter
3000-30000 MHz	10 - 1 cm	Ultra-short waves: Centimeter
30000 - 300000 MHz	10 - 1 mm	Millimeter

Table 17 shows an arbitrary subdivision of the radiowave range located between vibrations of sonic frequency and the infrared optical radiation. The corresponding oscillation frequency is given at the top of the table.

TABLE 17

/174



At the present time, electromagnetic waves in the centimeter and decimeter ranges are used for treating the organism directly for therapeutic purposes. This method is called microwave therapy.

§2. THERAPEUTIC DIATHERMY

The use of the thermal effect in conducting high-frequency electrical current through the tissues of an organism form the basis of a method called therapeutic diathermy. Since the penetrating effect of an oscillating sinusoidal current decreases considerably as the frequency rises and is negligible at frequencies on the order of 500 kHz, the current associated with such a frequency can be used for producing thermal effects in the tissue of an organism.

Diathermy employs frequencies on the order of 1.5-2 MHz, corresponding to a wavelength of 200-150 m.

The amount of heat q which is produced in a unit volume of uniform tissue through which high-frequency current passes is directly proportional to the square of the current density j^2 and inversely proportional to the specific electrical conductivity g:

$$q = k,\frac{j^2}{g}.$$

As mentioned above, the tissues of an organism also exhibit capacitance (see Fig. 97). However, the oscillation frequency in medium wave diathermy is not high enough so that the capacitance component of electrical conductivity is of any significance.

The active resistance of the tissue in an organism to high frequency current is much less than it is to direct current. This is explained by the fact that at high frequencies there is a current of polarization phenomena both in the electrodes and within the tissues of the organizm. For the sake of clarity, we can examine sample values for the specific (in Ω/cm) resistance of some tissues of the body at frequencies from 1 to 1000 MHz.

TABLE 18

Frequency in MHz	1	200	1 000
Blood	100	90	80
Muscle	170	120	84
Internal organs	200—300	120—180	80—120
Brain and nerve tissue	800—1 000	600—800	400—500
Fatty tissue	2 000—5 000	1 500—4 000	1 100—3 500

In addition, due to the presence of a stimulating effect in the presence of high-frequency tissue, it is possible to have /175

much higher current densities below the electrode, which makes it possible to reduce the transitional resistance between the electrode and the skin. All of this means that if the resistance of the object during galvanization (considering the effect of the e.m.f. of polarization) was measured in thousands and hundreds of ohms, then in diathermy under similar conditions this value is only measured in hundreds and even tenths of an ohm.

In diathermy, metal electrodes are applied directly to the surface of the body; they are linked by wires to the output terminals of an apparatus. The electrodes are held in place with an elastic strap (Fig. 150). In diathermy, the electrodes are often located transversely, one opposite the other, so that the region subjected to the effects will lie between them. It is important to keep in mind that the current will travel along the shortest distance between the electrodes. In actuality, the paths of the current between the electrodes can be quite complex and have numerous effects.

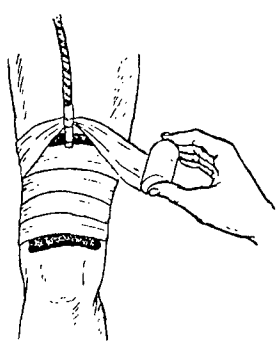


Fig. 150. Application of Electrodes in Therapeutic Diathermy.

When the electrodes are applied to the surface of the skin, the current passes successively through the contact between the electrode and the skin, the layer of skin and subcutaneous cells below each electrode, and then through the deep-lying tissues. The heat liberated at each of these areas in the circuit is inversely proportional to its electrical conductivity. Therefore, when using diathermy where the electrodes are placed in contact with the body, there is a considerable amount of heat liberated in the skin and the subcutaneous cells, which have lower electrical conductivity.

The electrodes used in diathermy are made of soft metal, usually lead, 0.5-1 mm thick and in different shapes. The area of the electrodes, calculated on the base of the permissible current density, is 0.010-0.015 a/cm^2 on the average. When the electrodes are applied to mucous membranes, the improved contact means that the current density can be raised to 0.03 a/cm^2.

The electrodes are usually made in the following sizes: 3× 3, 5 × 5, 5 × 10, 10 × 10, 10 × 20, and 15 × 20 cm. The electrodes must be made with rounded corners and a completely flat surface. The wires are attached to the electrodes by means of spring clips, or else they are soldered to them; only wires with high voltage insulation are used.

When applying the electrodes, it is necessary to ensure that the contacts between the electrode and the surface of the skin is

good, and that the electrode is fastened firmly to the body; beneath the clip there is a small piece of thin rubber.

In addition to the strip electrodes, special metal electrodes made of stainless steel in different shapes are also used; cylindrical ones for cysts, oval ones of different sizes for the vagina, cylindrical ones for the rectum, flat ones curved at an obtuse angle for the prostate, etc. For the extremities, one can also use electrodes in the shape of plastic baths, filled with a 10% solution of sodium chloride.

During the treatment, the patient must expect a sensation of heat immediately below the electrodes, depending on the magnitude of the current employed. If the patient should feel any sensation of burning beneath the electrode during treatment or when the current is being adjusted, it may be related to damage to the skin at this point (excoriation, abrasion). To prevent burning, it is necessary to place a small piece of insulating material below the electrode at this point (a piece of rubber). Frequently, a burning sensation is produced when the surface of the electrode is in poor condition (bent, rough, coated with oxide) or when the electrodes are not applied absolutely flat to the surface of the skin, thus creating an increased resistance at this point and raising the amount of heat liberated. In this case, it is necessary to check the condition of the surface of the electrode or to improve its contact with the body by using additional bandages or by placing a sandbag on top of the bandage. /176

By observing strictly the rules for applying electrodes and carrying out the treatment, the possibility of disturbing the contact between the electrodes and the patient's body is eliminated. It should be kept in mind that when the contact between the electrode and the patient's body is disturbed high-frequency sparks may be produced at this point that may cause a burn or even more serious damage in connection with the rectifying action of the spark, as a result of which there may be low frequency current pulses produced in the circuit which can be very dangerous to the patient if they reach a sufficient amplitude.

The high-frequency current passing through the tissue in local treatments may have a value of 1.5-2 A.

The resistance of the tissues located between the electrodes with a significant area, may reach an average of 40-50 Ω in local diathermy applications. This means that the voltage on the electrodes in diathermy must be 60-100 V. The power drawn by the apparatus which is used for all manner of local treatments must therefore be 180-200 W.

The formation of heat in the deep-lying tissues in the course of diathermy makes it possible to combine this method with others.

Heating the tissues in this way increases the effect of other treatments. A combination of this kind, e.g., increases the effectiveness of ionogalvanization, electrical stimulation of muscles, etc.

§3. SURGICAL DIATHERMY

The heat formed in the tissues when a high-frequency current passes through them can be used for both therapeutic and surgical purposes, especially in overcoming pathological changes in the skin.

To ensure a high heat intensity, an active electrode with a small surface area is used, beneath which is formed a rather high current density. A second electrode called the inactive electrode has a larger area and is attached to the body of the patient at a suitable location not too distant from the area being treated. A bipolar method is also used, with two active electrodes of small size.

There are two basic methods of surgical diathermy: diathermotomy (cutting the tissue) and diathermocoagulation (sealing or congealing tissue).

In diathermotomy the active electrode (Fig. 151, a) has the shape of a pointed blade, which cuts rapidly through the tissue when the current is turned on. This produces a narrow, even incision several millimeters deep, with smooth edges and almost no damage to vascular tissue. The biactive method is also used, in which the electrode has two insulated blades connected to the terminals of the apparatus. The mechanism by which the tissue is then cut is not completely clear. It has been suggested that the high-current density beneath the electrode produces such an intense liberation of heat that the moisture located in the skin cells is vaporized instantaneously (in a burst) and separates the tissue. /177
By moving the electrode more slowly, the tissue can be cut as the edges of the wound coagulate (diathermocoagulatomy).

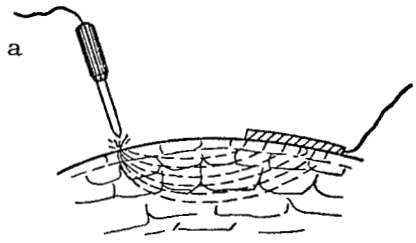
In diathermocoagulation, the active electrode is in the form of a small sphere or disk (Fig. 151, b) which is pressed against the tissue and then connected to a current of sufficient value so that it can be held in place for a certain period of time (several seconds) and then switched off. The tissue below the electrode is coagulated or even fused and then gradually atrophies. The advantage of diathermocoagulation over other forms of cauterization is the fact that the thermal effect can be delivered at a certain depth with minimum damage to adjacent tissues.

The biactive method of diathermocoagulation is also used. In this method, the electrodes are the ends of a forceps whose tips are insulated from one another; this device is connected by two wires to the output terminals of the apparatus. In perform-

ing the treatment, the tissue to be coagulated is pinched between the tips of the forceps (Fig. 152) and the current is allowed to flow for the desired period of time. The biactive method is particularly suitable for treating tissues protruding above the surface of the body.

The method of surface coagulation by means of high-frequency sparks is used when the electrode (usually in the shape of a sphere) is located a short distance above the surface of the body.

All of these methods of surgical diathermy are employed with local anesthesia.



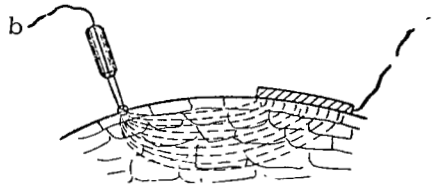


Fig. 151. Diagram of Location of Electrodes in Monoactive Surgical Diathermy.
a. Diathermotomy;
b. Diathermocoagulation.

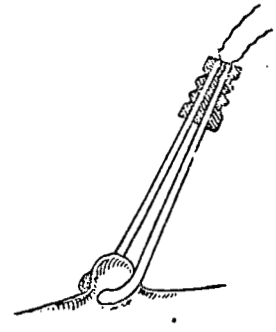


Fig. 152. Diagram of Biactive Diathermocoagulation.

Surgical diathermy requires much higher voltages between the electrodes than is the case in therapeutic diathermy. Consequently, the power of the apparatus must be much higher although it is used only for relatively short periods of time. The frequency of the current in surgical diathermy is usually the same as in therapeutic diathermy.

§4. D'ARSONVALIZATION

General and local d'arsonvalization were the first high-frequency methods employed in electrical therapy at the end of the last century. At that time, both methods were viewed simply as general and local effects of electromagnetic oscillations of high frequency; they were named after the French physician and physicist who suggested this method, "D'Arsonval's currents". D'Arsonval's currents were considerably attenuated electromagnetic oscillations whose effects were not accompanied by any noticeable thermal effect. This differentiated D'Arsonval's currents /178

from diathermal currents which were slightly attenuated oscillations of considerable power, producing a thermal effect. The oscillation frequency in d'arsonvalization is 200-300 kHz, corresponding to a wavelength of 1000-1500 m.

In the general method of treatment, the patient is placed inside a large solenoid (Fig. 153), connected to the oscillator circuit of the apparatus, and he does not feel any sensation. To check for the presence of a field, the patient is given a neon lamp to hold, which lights up when the field is switched on.

According to modern views regarding the nature of this phenomenon, a patient undergoing general d'arsonvalization is subjected to the general effect of an alternating high-frequency electromagnetic induction field, formed within the solenoid. The sharply attenuated nature of the oscillations means that this effect has a pulsed character with high amplitude values of current intensity and relatively long pauses.

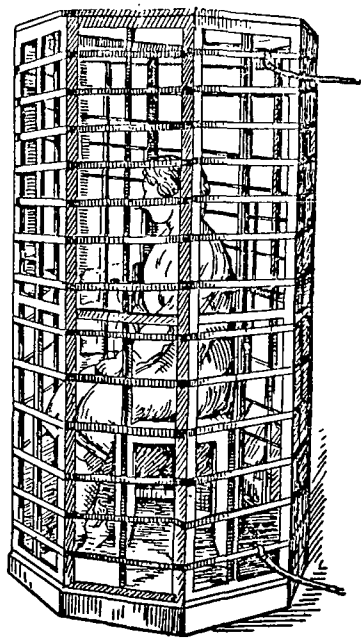


Fig. 153. Solenoid for General D'arsonvalization.

In local d'arsonvalization (Fig. 154) an electrode consisting of a molded glass rod filled with air evacuated to a pressure of 0.1-0.5 mm Hg is connected to one pole of the apparatus; this electrode has an insulated handle (Fig. 155). The electrode is moved over the surface of the body which is to be treated (when treating mucous membranes, e.g., in rectal treatment, the electrode /179 is mounted firmly). A high-frequency discharge is then produced between the electrode and the surface of the body, which is either quiet or in the form of a mild spark. The spark can be intensified by increasing the distance between the electrode and the surface of the body being treated.

The electrode acts as a capacitor (the rarefied gas is one electrode, the glass is a dielectric, and the surface of the object is a second electrode); it thus reduces the intensity of the discharge, which does not produce any painful sensations. The second pole of the apparatus is not connected directly to the patient; the circuit for the electrical oscillations is formed by the capacitance of the patient relative to

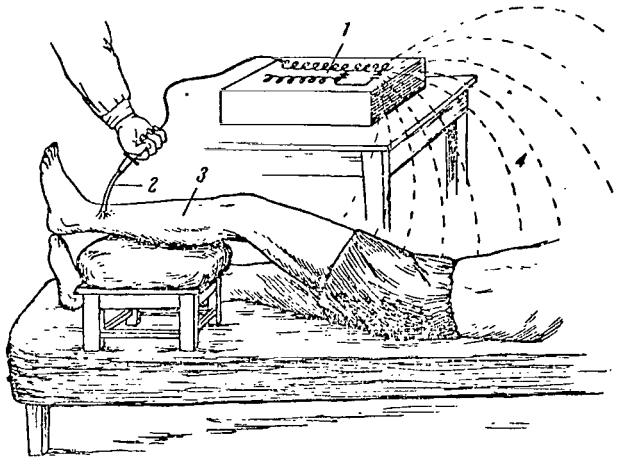


Fig. 154. System for Applying Local D'arsonvalization.

the surrounding conductors, especially the apparatus itself, as is shown in Figure 154, where 1 is the high-frequency generating circuit in the apparatus, 2 is the electrode, 3 is the object being treated, and 4 are the lines of force in the field.

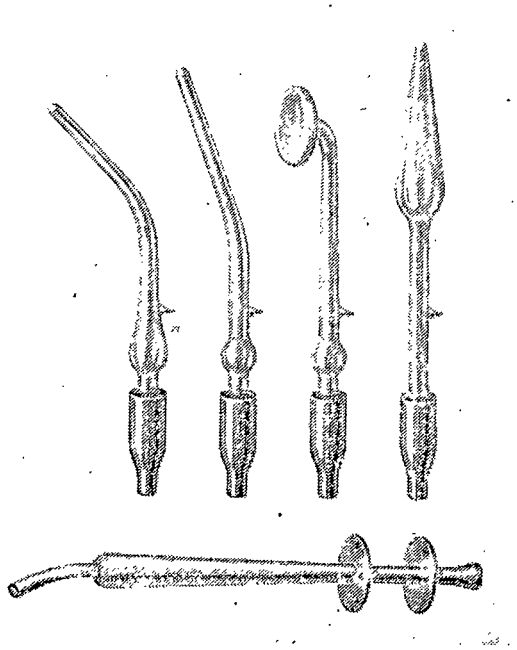


Fig. 155. Vacuum Electrodes for Local D'arsonvalization and Handle for Them (at Bottom).

Local d'arsonvalization produces a feeling of mild stimulation of the skin and a very small amount of surface heat. When the spark is used, a stronger sensation of stimulation is felt, but without any burning effect. A special electrode with a metal point on the end is used to produce burning.

Hence, the critical factor in local d'arsonvalization is the high-frequency electrical discharge produced between the electrode and the patient's body, which changes in intensity from "quiet", hardly producing any tangible sensations, to a mild spark which produces a stimulating effect and sometimes a slight sensation of burning. The special characteristic of the discharge is its pulsed nature, which does not cause any significant thermal effects.

The apparatus for general

or local d'arsonvalization must produce electrical oscillations of pulsed type, insignificant power, and high voltage. In local d'arsonvalization, the maximum (amplitude) voltage in small instruments reaches several thousand volts while in larger instruments it reaches tens of thousands of volts. In general d'arsonvalization, the high-frequency voltage supplied to the solenoid is much less.

§5. INDUCTOTHERMY

Wide use has been made recently of a method for generating a high-frequency magnetic field in the vicinity of the body, thus producing eddy currents in the tissues by induction; this method is called inductothermy. /180

In inductothermy, a portion of the body is subjected to the action of a high-frequency magnetic field, formed by a coil through which a high-frequency current passes. The eddy currents which are then induced in the current-conducting tissues of the body, heat the tissues. The process of inducing eddy currents in the tissues of the body is shown schematically in Figure 156, a. In the picture, the dotted lines represent the lines of force in the magnetic field; the solid lines show the eddy currents.

An equivalent electrical circuit for inductothermy is the high-frequency transformer connected to a resistor, which is equivalent to the resistance of the tissues in the body (Fig. 156, b).

The amount of heat q which is liberated per unit time per unit volume in a uniform current-conducting tissue is directly proportional to the square of the frequency of the oscillations ν^2, the square of the intensity H^2 of the magnetic field, and the specific electrical conductivity g of the tissue:

$$q = k_2 \nu^2 H^2 g.$$

Therefore, the formation of heat will be maximum in the liquid media within the body (blood, lymph, etc.), which exhibit the best electrical conductivity, while it will be weakest in the tissues, in muscles, e.g.

Much else is involved in the action of therapeutic diathermy and inductothermy on the tissues of the body. In both cases, the tissues are subjected to the action of high-frequency current which in the first case is applied to the body by means of contact electrodes, and in the second place is applied by induction using a coil of wire through which the current passes. The high-frequency current in both cases represents a controlled oscillation of ions around a middle position, accompanied by the formation of heat. By comparison with diathermy, inductothermy has certain advantages which include primarily the fact that it lacks a number of the disadvantages which are connected with the need for a con-

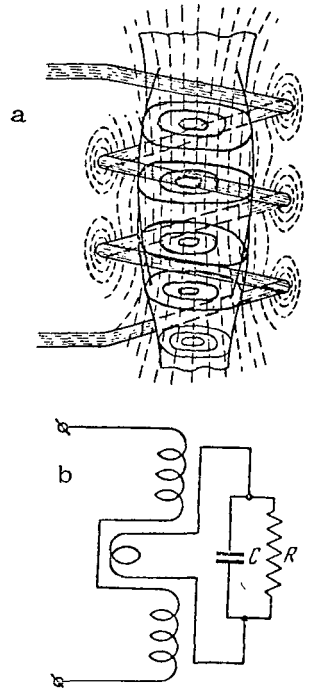


Fig. 156. Schematic Representation of the Principle of Inductothermy.
a. Eddy Currents in Tissues.
b. Equivalent Electrical Diagram.

tact application of the electrode and secondly because the dissipation of heat takes place mainly in the deep-lying tissues of the organism.

In order for the spiral electrode to produce a significant magnetic field at a high oscillation frequency, it is necessary for certain conditions to be fulfilled. In order to reduce the electrical component of the field in inductothermy, it is important to ensure that the frequency of the oscillations is not too high and that when the coils are manufactured, the gaps between the turns as well as between the turns and the patient's body are not too large. The most effective oscillation frequency for inductothermy is between 10-15 MHz, corresponding to a wavelength of 30-20 m.

The apparatus for administering inductothermy consists of a high-frequency generator powering an electrode in the shape of a flexible cable, which is used to form a solenoid or coil. The coil which forms a magnetic field can be cylindrical or flat. A cylindrical coil (Fig. 157, a) is usually used in administering treatment to the extrem-/181 ities: the portion of the extremity which is to be treated is placed among the coils of the cable. A flat spiral is placed on the surface of the area to be treated, as represented schematically in Figures 157, b and c. The flat spiral produces a field which is represented schematically in Figure 158 (in Fig. 158, 1 represents the turns of the cable, which forms the spiral; 2 are the lines of force in the field; 3 is the object being treated). The lines of force in this field penetrate into the subjacent tissue to a relatively shallow depth on the order of 5-8 cm.

The intensity of the magnetic field within the cylindrical spiral in the immediate vicinity of the coils has a maximum value; it then gradually decreases, so that at a certain distance from the coils of the spiral a zone of more uniform field is obtained.

Due to the nonuniform distribution of the field intensity, the heating of a uniform body by induction currents, when the

latter is placed in this field, will also be nonuniform.

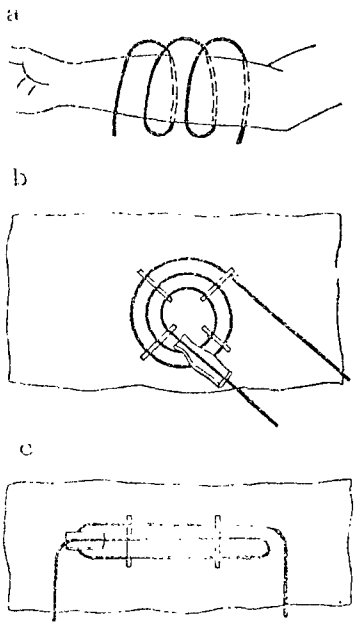


Fig. 157. Diagrams of Arrangement of Cable Used in Inductothermy.

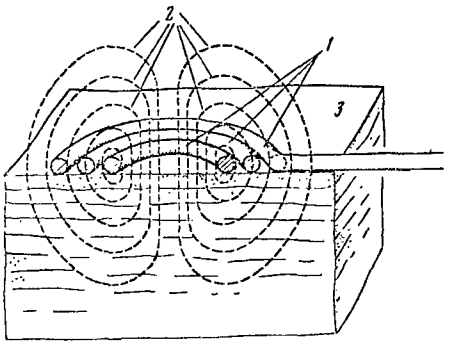


Fig. 158. Schematic Diagram of Lines of Force in a Field Produced by a Flat Spiral.

Figure 159 is a schematic diagram of the relative distribution of temperature within a uniform current-conducting body of diameter d, located within a solenoid of diameter D, through which is flowing a high-frequency current: (a) without a gap and (b) with a small gap. As we can see by comparing the graphs, in the second case a more even distribution of temperature is obtained within the body. This makes it necessary in inductothermy to have a small gap between the turns of the spiral and the object.

The gap required between the turns of the cable and the surface of the body is usually produced by several layers of linen placed between the body and the turns of the cable.

In making spirals (both flat and cylindrical ones), it is necessary to ensure that the gap between adjacent turns is at least 1 cm; this is accomplished by winding the cable on a special jig. An important rule in making a flat spiral is to provide additional insulation (or a gap) between the turns of the spiral and the inner end of the cable which intersects them. The cable is fitted with a special insulating sleeve for this purpose.

Regardless of the significant difference in the possible configuration of the flat or cylindrical spirals, it is necessary when making them to produce a certain number of turns which will be most effective; this number depends on the characteristics /182 of the input circuit of the apparatus, and is usually described in the instructions.

In addition to the cable which acts as a universal electrode, the apparatus is also fitted with two disk applicators. A disk applicator is a tightly coiled flat spiral with a certain diameter of the windings, mounted in a plastic housing (see Fig. 214).

At the present time, a new type of electrode for inductothermy has been developed for use at higher frequencies, called the eddy-current electrode. The electrode (Fig. 160) consists of a specially formed spiral 2 and an air capacitor 3, mounted in a plastic housing 1 and covered by a cap 4. The spiral and capacitor form an oscillating circuit which is resonant. Electrical field in the spiral, formed by the capacitances between the turns and the capacitance between the spiral and the patient's body, is reduced to a minimum, so that the electrode acts on the patient's body with a magnetic field. As a result of this, the conditions for producing heat in heat conducting tissues (mainly muscles) is better as compared to the effect of the flat spiral used in inductothermy, whose field always contains some electrical component which produces heat in the skin layer and the subcutaneous cells.

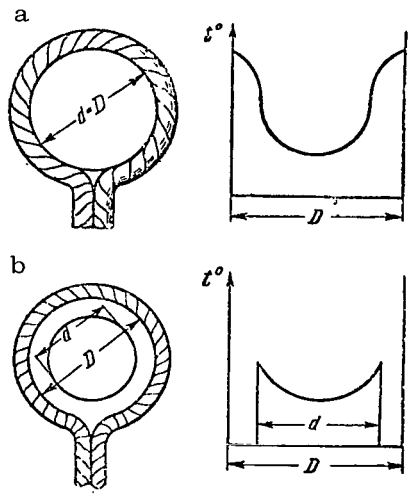


Fig. 159. Graphs Showing the Distribution of Temperature Within a Uniform Body During Inductothermy. a. Without Gap; b. With Gap.

The sensations felt during inductothermy can be attributed to the production of heat in the deep-lying tissues, the intensity of which is proportional to the absorptivity of the oscillations. This makes inductothermy different from the other types of high-frequency therapy, diathermy and UHF field therapy, in which the feeling of heat is more on the surface. A feeling of burning within a limited area, particularly on the surface of the body, means that the electrode cable is too close to the body, so that a portion of a field with increased intensity is being formed at this particular spot, thus causing more intense heat formation. This phenomenon can be eliminated by ensuring that there is the required gap between the cable and the patient's body. /183

The apparatus for inductothermy is a generator of electrical oscillations which uses a relatively low working voltage (90-120 V under load), and a power of 150-200 W.

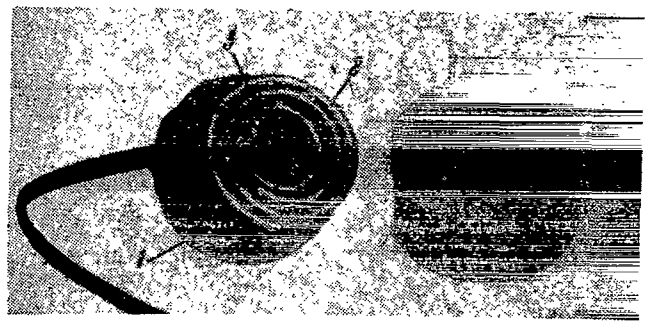


Fig. 160. Eddy-Current Electrode.

§6. THERAPY USING AN UHF ELECTRICAL FIELD

In the preceding, we have discussed phenomena which take place in the tissues of an organism under the influence of constant electrical fields: in solutions of electrolytes, there is directed motion of ions, while in dielectrics there is polarization which is primarily orientational. Under the influence of high-frequency electrical fields, these processes can have an alternating, oscillatory character. This means that there will be collision of oscillating particles with the surrounding particles of matter and the temperature of the material will rise in the final analysis, i.e., it will be heated.

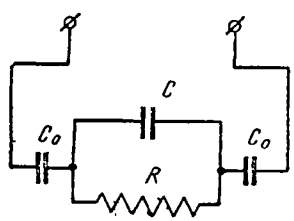


Fig. 161. Equivalent Electrical Diagram of UHF Therapy.

The amount of heat q formed per unit time in a unit volume of solution of a uniform electrolyte, is directly proportional to the square of the intensity E^2 of an electrical field and the specific electrical conductivity g of the solution: $q = K_3^1 E^2 g$.

The amount of heat q formed in a unit time in a unit volume of a uniform dielectric is directly proportional to the frequency ν, the dielectric constant ε, the square of the intensity E^2 of the electrical field, as well as the tangent of the so-called loss angle tanδ : $q = K_3^1 \nu \varepsilon E^2 \tan\delta$ (the loss angle is the angle δ between the vectors of the active and reactive components of the current, which depends on the nature of the dielectric).

In the presence of an UHF electrical field in the tissue of an organism, which is not uniform in its electrical properties,

it is possible that certain field intensities and oscillation frequencies may produce certain different amounts of heat in different tissues depending on the value of the dielectric constant, the tangent of the loss angle, and the specific electrical conductivity of these tissues. This phenomenon is called the thermoselective effect of an UHF electrical field.

It is difficult to detect the thermoselective effect of an UHF electrical field in a living organism. However, clinical observations indicate that to a certain degree, the selectivity of the action of electrical fields of different frequencies on different tissues in the organs does in fact operate.

Frequencies corresponding to wavelengths of 6-8 m are used for UHF electrical field therapy. The effects on a given region of the body are produced by means of capacitor electrodes, which are metal disks with insulated handles, which are either applied directly to the surface of the body at the region which is to be treated or else are located a short distance away (with a gap).

The equivalent electrical circuit used in UHF therapy (Fig. 161) consists of the resistance R and capacitance C of the tissues of the organism itself, connected in parallel with one another, and two capacitances C_0 connected in series, produced by the gaps between the electrodes or their insulators.

The electrodes used in UHF electrical field therapy are mounted so that the area of the body being treated is located between them. Figure 162 shows a diagram of a possible location of the /184
electrodes: (a) transverse without a gap; (b) transverse with a gap; (c) longitudinal (tangential) without a gap.

The location and area of the electrodes determines the distribution of the potential formed in the tissues by the electrical field. In Figure 162, we see a schematic representation of the position of the lines of force of the electrical field produced with the electrodes in different positions, without taking differences in the electrical properties of various tissues in the body into account. From these illustrations, we can see that (a) with the electrodes located transversely without a gap (Fig. 162, a), the electrical field is concentrated in the volume of tissue located between the electrodes; the intensity of the field immediately below the electrodes is somewhat greater than it is farther down in the tissue; (b) with a transverse location of the electrodes and gaps below them (Fig. 162, b), the intensity of the electrical field in the location of the electrodes is lower, but the electrical field occupies a much greater area and its intensity is much more uniform; (c) with the electrodes in a longitudinal position (Fig. 162, c), the electrical field has the greatest intensity in the surface region between the ends of the electrodes.

Hence, in order to produce a more intense thermal effect

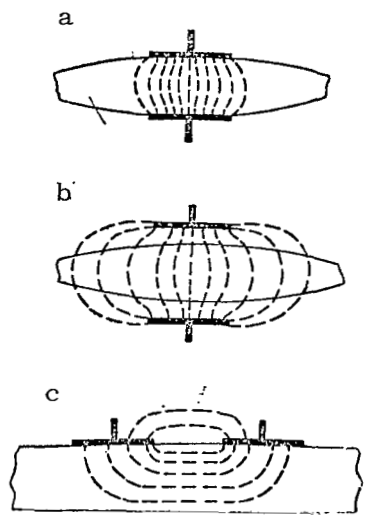


Fig. 162. Diagram of the Location of Electrodes When Using UHF Electrical Field Treatment.

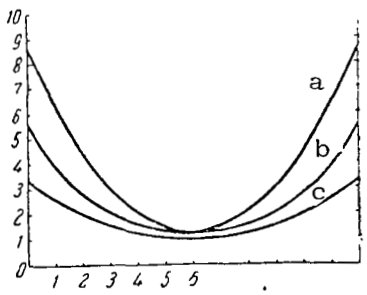


Fig. 163. Graph of Temperature Distribution in a Uniform Dielectric Under the Influence of an UHF Electrical Field. (a) Without a Gap Below the Electrode; (b) With a 1-cm Gap; (c) With a 2-cm Gap.

in a limited portion of the tissue near the surface, small electrodes must be applied with no gaps between them and the tissue. To treat tissue located deeper within the body, it is necessary to use electrodes that have a gap between them and the body; however, this calls for a much greater power expenditure due to the dissipation of a considerable amount of this energy in the space surrounding the electrodes.

Figure 163 shows the curves of temperature distribution within a uniform dielectric when using electrodes without a gap (curve a) and with 1 cm and 2 cm gaps (curves b and c, respectively). The thickness of the dielectric layer is 12 cm, represented along the horizontal axis of the graph; the vertical axis represents the degrees of temperature increase. As we can see from the graph, the use of gaps makes the heating more uniform throughout the entire thickness of the dielectric, although the total amount of heat dissipated in the dielectric is less.

It should be mentioned that when using UHF therapy, the heating effect has a more or less superficial nature even when electrodes are used with a gap. This is because the skin is more richly supplied with temperature censors than are the tissues located further down.

Hence, the comparison of the relative distribution of heat in tissue when using different methods of high-frequency therapy /185 indicates (in a somewhat schematic form) that if the heat is applied directly to the tissues located on the surface during diathermy (the skin layer and subjacent cellular layers), than in inducto-

thermy (with the tissues located deeper within the body (especially in the muscles and tissues which are well supplied with liquids), the effect of the UHF electrical field (especially with a gap) produces a much more uniform heat distribution in both the surface tissues and those located deeper within the body.

The phenomenon of a local feeling of heat somewhere on the surface of the skin may be produced by significant concentration of electrical charges on conductive (moist) surfaces, thus forming a potential difference which causes considerable local conduction currents. Similar phenomena can be found, e.g., under the conditions when the electrodes are applied directly to the body and the skin sweats beneath them. To ensure the proper effects, it is necessary to place some absorbent cloth beneath the electrodes.

It is generally considered that an UHF electrical field has a particular, so-called oscillatory effect on the tissues of the organism, mainly on those containing nerve receptors; this effect has nothing to do with the thermal effect, and occurs even when the latter is absent. By the oscillatory effect, we mean the biological reactions of the organism which are related to the small changes in the cellular and even molecular structures of the tissues, induced by the UHF electrical field. This makes it possible to use the electrical field not only as a thermal method (i.e., to heat the body) but also as a low-heat method which does not heat the body very much. The existence of a field between the electrodes in this case can be revealed by placing a neon bulb between them to see whether it lights.

For local treatment, with small electrodes, an apparatus operating at 30-40 W is adequate for low-heat treatment. On the other hand, a power on the order of 50-80 W is required for a treatment involving thermal effects and large electrodes without gaps (or in low heat treatment with gaps below the electrodes). It is necessary to have an apparatus capable of delivering 300 W of power for treatment involving thermal effects with large electrodes and with gaps below the electrodes.

The high-frequency potential at the electrodes in apparatus for UHF therapy can change within broad limits depending on the nature of the load placed on the apparatus (the area of the electrodes, the size of the gap below the electrodes, etc.). Its maximum value, corresponding to operation of the apparatus without a load, reaches 300-400 V in high power devices or 120-150 V in low power instruments. With an active load, the potential of the apparatus drops to about 100-150 V in high power instruments and 40-60 V in low power instruments.

§7. THERAPY USING A UHF PULSED ELECTRIC FIELD

In recent years, the State Institute of Physical Therapy has devised a method of stimulating the organism with a UHF electrical field in a pulsed regime, called pulsed UHF therapy. In the usual method, the UHF electrical field formed between the electrodes has a continuous nature, as shown in the graph in Figure 164, a. In this method, a field is formed and acts on the tissue in separate portions or pulses (Fig. 164, b), lasting several microseconds and separated by pauses which exceed the length of /186
the pulse itself by hundreds of times. The intensity of the field in the pulse reaches values which are tens of times greater than in a constant regime. In all other respects, the situation is the same (design of the electrodes, their position, etc.) and completely analogous to the method used in the continuous regime.

The physical processes which take place in the tissues of the organism under the influence of an UHF pulsed electrical field are analogous in principle to those processes which take place with the constant regime. They involve an oscillating motion of the ions in solutions of electrolytes (conductivity current) and orientational oscillations of molecules in the dielectric (displacement current). However, the high intensity of the electrical field and the pulsed nature of its action lead us to expect a different biological effect.

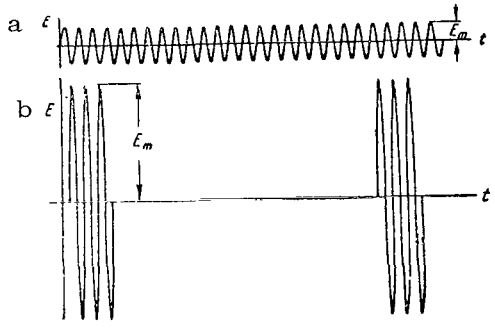


Fig. 164. Graph of Oscillations in a UHF Electrical Field.
a. With Constant Regime;
b. With Pulsed Regime.

In the pulsed regime, the effective value of the field intensity is low, and the thermal effect is similarly insignificant. On the other hand, the maximum value of the field intensity produced by the oscillating action is considerable. Hence, in the pulsed regime it is possible to achieve an intense oscillating effect without a significant thermal effect.

Under the influence of the oscillations of the UHF electrical field, the structures of the complex albumin molecules undergo changes; these include, e.g., molecules of enzymes, etc., which may undergo changes in the ion concentration in the boundary cell membranes, changes in the hydration and dehydration conditions of the molecules, etc. All of these phenomena change the functional state of the cells and the effect of such a field on the central or vegetative nervous systems may produce considerable functional changes in the organism.

§8. MICROWAVE THERAPY

Electromagnetic waves on the 12.6 cm wavelength are used in the Soviet Union for therapeutic purposes. Studies are also being carried out on the 65 and 3 cm waves.

In microwave therapy, the area of the body being subjected to the treatment is irradiated by a directed flux of electromagnetic waves similar to photo-thermal radiation (Fig. 165). The source of radiation in this treatment is a special lamp 1 powered by a generator 2 which produces high-frequency electrical oscillations. The electromagnetic waves strike the surface of the body and are gradually absorbed, penetrating to a shallow depth. A 12.6 cm wave heats tissues down to a depth of 5-6 cm (this value is somewhat less for centimeter waves). The action of the electrical component of the electromagnetic field of the waves in the tissues of the organism cause the appearance of currents of ionic conductivity (oscillation of ions) and orientational polarization of molecules which accompany the heating of the body.

The energy losses in the orientational polarization depend /187
on the oscillation frequency. The cohesive forces between the molecules inhibit the oscillations of polar molecules in an alternating electrical field, so that these oscillations are retarded out of phase relative to the oscillations in the applied field. This phenomenon is called dielectric hysteresis and becomes noticeable only at very high frequencies, i.e., in the range of the decimeter and centimeter waves. When the frequency of the electrical field is increased, the dielectric hysteresis initially increases and the absorption of the energy of the oscillations by the tissue likewise increases. The maximum value is reached by the dielectric hysteresis at a field frequency which corresponds to the period of the relaxation oscillations of the molecule (the time or period of relaxation is called the return time of the molecules to their original position with an instantaneous suspension of the action of the maximum intensity field). With a further increase in frequency, the match between the oscillations in the applied field and the oscillations in the polar molecule breaks down, hysteresis decreases, and the absorption of energy by the tissue likewise decreases.

Solutions of electrolytes, which are viewed only as ionic conductors at a very high oscillation frequency relative to a high-frequency current must not be viewed solely from the point of view of the movable charges which they contain (ions), but also the dielectric properties of the water which acts as the solvent, must be taken into consideration.

Experiments have shown that in the microwave range the fundamental processes which cause absorption of energy by the organism and the corresponding thermal effect are not only the oscillations of the ions and the electrolytes but mainly the relax-

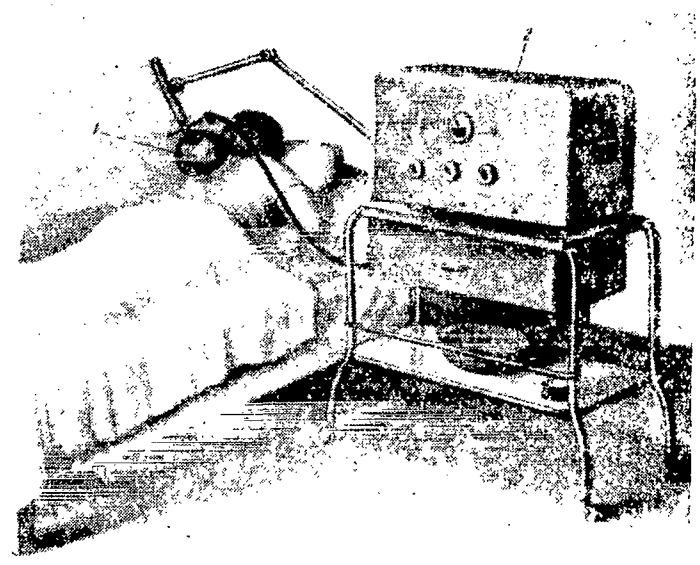


Fig. 165. Microwave Irradiation Treatment.

ation oscillations of the water molecules. The relaxation time of the latter at a temperature of 20° is on the order of 10^{-11} sec, corresponding to a wavelength of 3 mm. Therefore, as the wavelength decreases, the energy absorbed by the water increases more and more. From this it follows (and has been proven by experiment) that the greatest absorption of microwave energy takes place in the tissues which contain the largest amounts of water (blood, muscle, etc.). On the other hand, energy absorption is /188 minimal in fatty tissue and bone. This is the reason for the different physiological effect produced by microwaves as compared to UHF electrical fields.

It should be mentioned that although microwave therapy is characterized by a more concentrated thermal effect than is UHF electrical field therapy, due to the directed action of irradiation, it can be used for nonthermal (oscillating) effects on the tissue of an organism. According to contemporary views, the quantity of radiation energy absorbed by a molecule of a substance places that molecule in an excited state, which can be terminated either by a thermal effect when the molecule strikes another, nonexcited molecule, or by a rearrangement of atomic groups within the molecule itself. Such a rearrangement is the physical and chemical basis for the nonthermal effect of the radiation.

The method of performing microwave therapy involves directing a stream of radiation at the portion of the body to be treated by means of a reflecting (see Fig. 165) or wave-guide (see the description of the apparatus below) radiator, located 5-10 cm from the surface of the body. The radiator is selected so that

it will conform in shape and size to the part of the body being irradiated.

The so-called contact method is also employed, in which a current of electromagnetic waves is directed at the surface of the body by means of a localizer made of a solid dielectric (ceramic is usually used). The localizer is applied directly to the area to be treated, which must have a small area.

The intensity of the radiation is regulated so that a pleasant warmth is felt in the area which is being irradiated. The heat must not be allowed to reach an unpleasant or painful level. Irradiation lasts 10-15 min; sometimes a mild erythema appears on the skin following treatment, and the feeling of warmth remains. The erythema disappears after 10-15 min.

PART 2

GENERATOR OF ELECTRICAL OSCILLATIONS

§1. OSCILLATOR CIRCUIT

The operating principle of an ideal oscillator circuit (i.e., one which does not have an active resistance), is shown in the graphs and diagrams in Figure 166. Let us imagine that a capacitor is charged to a voltage of U_c at a certain moment and that an electrical field is formed in it (Fig. 166, 1), and that the action of the external voltage ceases. The capacitor begins to discharge through an induction coil producing a current I_k in the circuit, forming a magnetic field in the coil. An electromotive force of autoinduction is produced in the coil, which resists rapid increase in the current. The current I_k increases gradually, while the voltage at the terminals of the capacitor also decreases. When the voltage at the terminals of the capacitor has fallen to zero (Fig. 166, 2), the current and the magnetic field in the coil reach their maximum value.

Then the current gradually begins to decrease, aided by the action of the electromotive force of autoinduction in the coil which changes its direction. The current gradually charges the capacitor again, but with opposite polarity of the plates. When /189
the current and the magnetic field in the coil have fallen to zero, the capacitor is again charged (Fig. 166, 3). The process is repeated, but the current in the circuit will have the opposite direction (Fig. 166, 4), while the capacitor is charged with the former polarity at the end of the cycle (Fig. 166, 5).

The frequency of the oscillations in an ideal circuit is:

$$\nu_0 = \frac{1}{2\pi\sqrt{LC}},$$

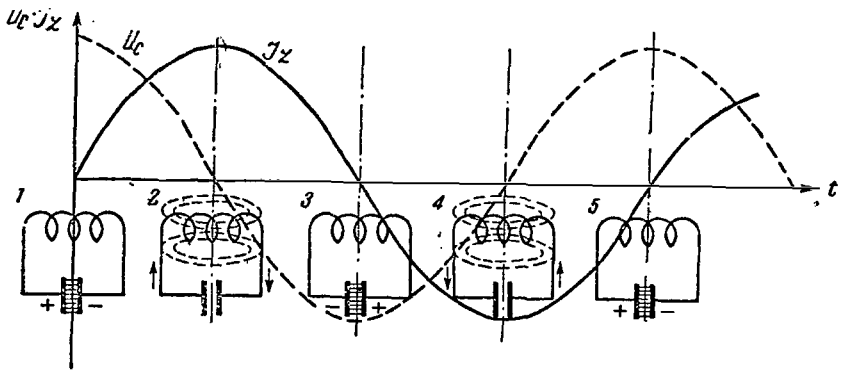


Fig. 166. Diagram and Graph Showing Operation of Oscillator Circuit.

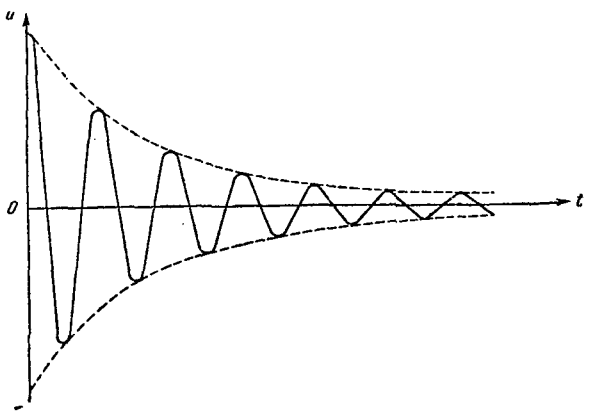


Fig. 167. Graph of Damping Oscillations

where L is expressed in henries (h), C is expressed in farads, and ν_0 is expressed in Hertz.

In the ideal circuit, in addition to the inductance and the capacitance, there is also an active resistance R in which a portion of the energy is liberated. This means that the oscillations occur with a gradually decreasing amplitude and are called "damping".

The graph of damping oscillations is shown in Figure 167.

In this case, the frequency of the oscillations $\nu = \nu_0 \sqrt{1 - \frac{R^2}{4\rho^2}}$, where $\rho = \sqrt{\frac{L}{C}}$ is the wave resistance of the circuit.

Since $\frac{R^2}{4\rho^2} \ll 1$, in generator circuits, this value can be dis-

regarded and the frequency calculated by the formula given above.

In order to ensure that the oscillations in the circuit are nondamping, it is necessary to replace the energy lost in the active resistance. To do this, it is necessary to restore the voltage to the initial level on the plates of the capacitor, by charging it from an external energy source. In the initial period of the development of the production of electrical oscillations, the power for an oscillator circuit was produced by alternating current from a transformer by means of a spark discharge. A device of this kind is called a spark generator; over the years, it has become the main component of instruments for diathermy and both general and local d'arsonvalization. /190

A peculiar feature of spark generators is the fact that they form oscillations over a relatively wide range of frequencies. This is not very important for therapeutic applications, but it does produce intense radiation that causes radio interference (see below). In conjunction with an effort to combat radio interference, the production of medical devices with spark generators was suspended in 1950.

§2. VACUUM-TUBE GENERATOR

An elementary circuit showing a vacuum-tube generator with self-excitation is shown in Figure 168. The generator consists of a triode 1, connected in series with an oscillator circuit (capacitor 2 and inductance 3) and a source of direct current. Coil 4 is connected between the grid and the cathode of the tube, and is linked by induction to the coil in the oscillator circuit; it is called a feedback coil.

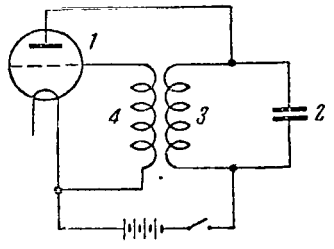


Fig. 168. Schematic Diagram of Vacuum-Tube Generator With Self-Excitation.

The operation of the generator can be represented schematically as follows. When the power supply is switched on, a current which increases in magnitude is produced in the circuit consisting of the tube and the coil. As the current increases in the coil, an e.m.f. of induction is formed which produces a positive potential on the grid of the tube. The current then continues to increase up to a certain maximum value, determined by the tube characteristic. At the same time, capacitor 2 charges. When the current reaches its maximum value, the induction process in the coil ceases and the magnitude of the e.m.f. of induction (and therefore the potential on the grid) drops to zero. This causes the current in coil 3 to drop, so that a negative potential appears on the tube grid; this causes the current to drop still further until the tube is com-

pletely blocked. The capacitor then discharges through the coil and the oscillation process begins.

When the process has stabilized itself, the current which passes through coil 3 induces an alternating potential in coil 4 and therefore on the tube grid; the frequency of this potential is the same as that of the oscillations in the circuit. This produces pulses in the anode current of the tube. The alternating component of the anode current of the tube, charges the capacitor and therefore the oscillations remain undamped due to the energy from the power source.

The method by which the anode circuit is powered differentiates vacuum tube generators with series (Fig. 169, a) and parallel (Fig. 169, b) power. In both circuits, L_a and C_a constitute an oscillator circuit connected in the anode circuit of the tube; the coil in the feedback circuit L_g is connected to the grid circuit; L is a choke which separates (blocks) the power source to protect it from high-frequency oscillations, and C is a capacitor which separates the oscillator circuit from the power supply circuit (Fig. 169, b). /191

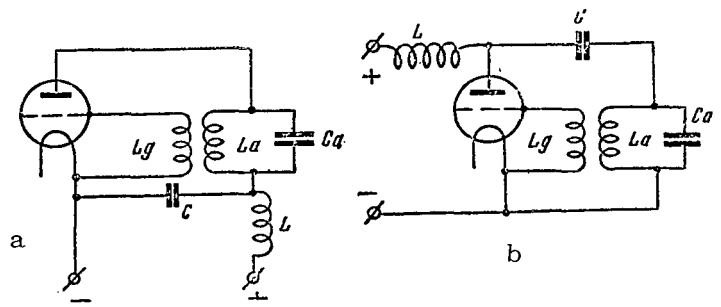


Fig. 169. Schematic Diagram of Vacuum Tube Generator. a. Series Power; b. Parallel Power.

When the tubes are powered by a source of direct current, the oscillations in the anode circuit have an undamped appearance and an amplitude which is constant in value (Fig. 170, a). When the tube is powered by rectified, pulsed voltage, e.g., from a two-cycle rectifier without a filter, the oscillations have the appearance of modulations according to the shape of the supply voltage (Fig. 170, b); finally when the tube is powered by alternating current, the oscillations have an interrupted, amplitude-modulated appearance (Fig. 170, c), corresponding to the half-cycle rectifier circuit. (In this case, the generator tube itself will fill the role of rectifiers).

In addition to an inductive link between the oscillator circuit and the grid circuit (see Fig. 169), some generators also

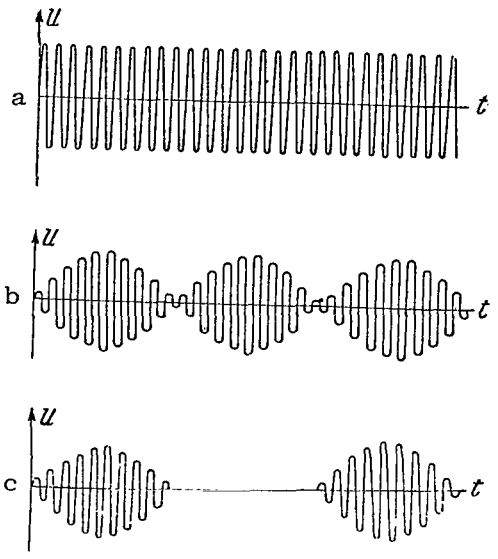


Fig. 170. Graph of Electrical Oscillations in Generator Power. a. DC; b. Rectified Current; c. AC.

use an autotransformer (Fig. 171, a) and a capacitor link (Fig. 171, b). These circuits are called three-point. Note that in the circuit shown in Figure 171, a, the grid circuit also contains a separating capacitor, which separates the grid from the negative potential of the power source, which is connected in parallel with the oscillator circuit. The capacitor is shunted by a leak resistor.

Figure 172, a shows a generator diagram with self-excitation, in which the oscillator circuit 2-3 is connected directly to the grid circuit of the tube. The oscillations are sustained by an inductive link between the circuit coil and the coil 4 connected to the anode circuit of the tube. Coil 4 is also inductively linked to the circuit in which the energy of the high-frequency oscillations is employed. /192

Figure 172, b shows a circuit in which there are two oscillator circuits linked by a capacitor 4: in the anode 2-3 and the grid 2^1-3^1 circuits of the tube. The operation of all of these circuits is analogous in principle to the operation of the elementary circuit discussed above (Fig. 168).

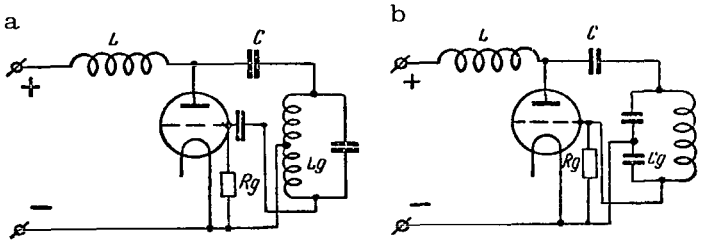


Fig. 171. Schematic Diagram of Vacuum-Tube Generator. a. With Autotransformer; b. Capacitive Feedback to the Grid.

In determining the required values of the capacitors and

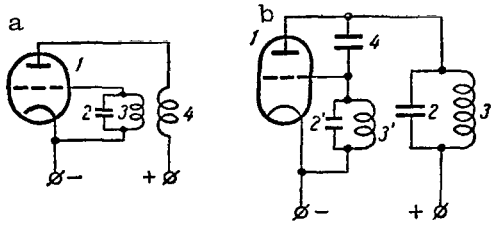


Fig. 172. Circuits for Inclusion of an Oscillator Circuit in the Generator With Self-Excitation in the Grid Circuit by Means of Different Methods of Feedback.

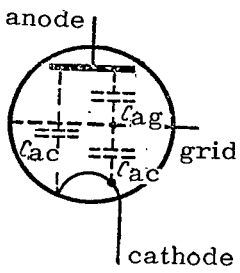
inductances for the oscillator circuit of a vacuum tube generator, it is necessary to consider the interelectrode capacitances and inductances of the leads of the tube itself. This is of particular importance in the ultrasonic oscillation frequencies, when (e.g.) the interelectrode capacitances of the tube become commensurable with the capacitance of the oscillator circuit. The interelectrode capacitances of the tube are shown schematically in Figure 173: C_{ac} is the capacitance between the anode and the grid, called transient; C_{ck} is the capacitance between the grid and the cathode, called input, and C_{ak} is the capacitance between the anode and the cathode, called output.

As we can see by comparing Figures 172 and 174, the interelectrode capacitances in the circuits shown in Figure 172 are connected in parallel with the capacitances of the oscillator circuit (Fig. 172, a) or the capacitance connecting the oscillator circuit with the grid (Fig. 172, b). At very high frequencies, the interelectrode capacitances in many cases are of sufficient magnitude to cause an oscillation process linked with the grid, so that the internal capacitors are not included in the circuit (Fig. 174, a and b, with symbols the same as in Fig. 172, a and b). Similarly, an oscillator circuit (Fig. 174, a) consists only of an induction coil and the interelectrode capacitance within the tube.

To ensure the operating regime of the generator in the most favorable portion of the characteristic, a negative potential, called the bias, is applied to the control grid of the tube; this bias is constant in value. For this purpose, it is possible to use either a separate source of voltage or an automatic bias formed by the voltage drop from a constant component of the anode or grid current across a special resistor connected to the proper point in the circuit.

Bias produced by means of anode (cathode) current (Fig. 175) /193 is achieved by connecting an active resistor R_k in the cathode circuit of the tube. In order to obtain a constant bias, the resistance is shunted by capacitor C_k, which acts as a relatively small resistance for the variable component of the anode current.

Bias produced by the grid current is produced as a result of the passage of a constant component of the grid current through an active resistance R_g, connected in the grid circuit. Two methods



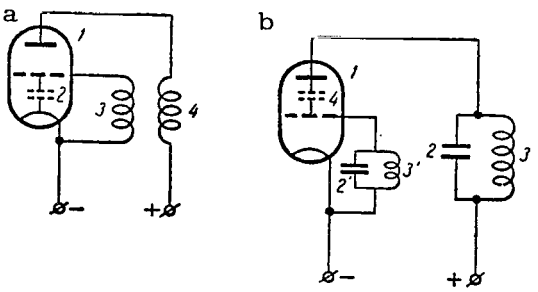


Fig. 173.

Fig. 174.

Fig. 173. Schematic Diagram of Interelectrode Capacitances in a Three-Element Tube.

Fig. 174. Schematic Diagram of Vacuum-Tube Generators Using Interelectrode Capacitances.

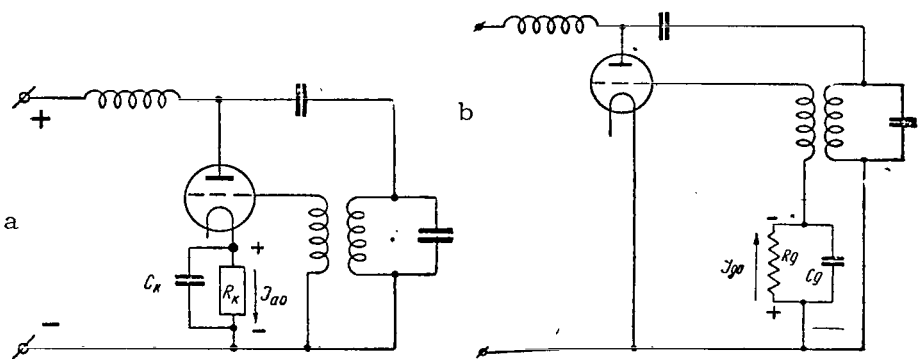


Fig. 175.

Fig. 176.

Fig. 175. Schematic Diagram of a Bias Resistor Included in the Cathode Circuit of a Tube.

Fig. 176. Schematic Diagram of a Bias Resistor Connected as a Follower in the Grid Circuit of a Tube.

of connecting the bias resistor in the grid circuit are possible: in series (Fig. 176) and in parallel (Fig. 177). In the first case, the resistance is shunted by capacitor C_g during the alternating component. In the second case, choke L_g and capacitor C_p are connected to the grid circuit to separate the constant and alternating components of the grid current and to block the corresponding circuits.

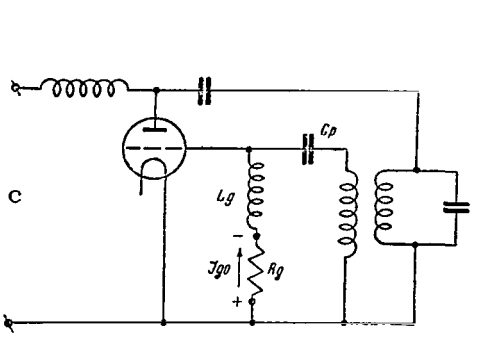


Fig. 177.

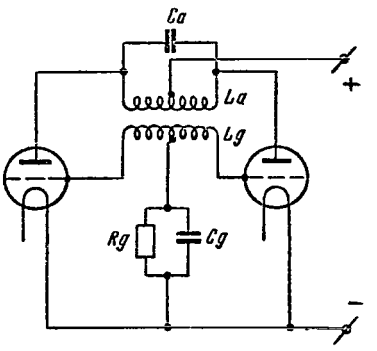


Fig. 178.

Fig. 177. Schematic Diagram of Bias Resistor Connected in Parallel in the Grid Circuit.

Fig. 178. Highly Simplified Two-Stage Circuit for Vacuum Tube Generator.

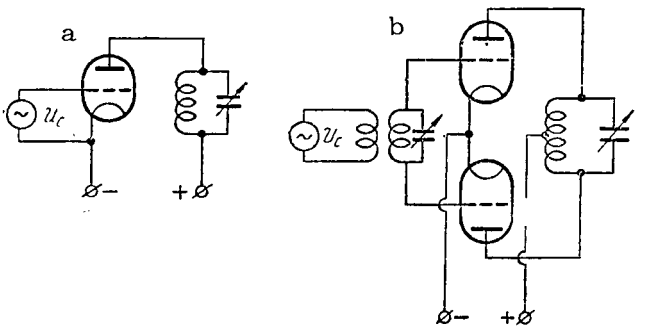


Fig. 179. Schematic Diagram of Generator Using Independent Excitation. a. One Stage; b. Two Stage.

The bias resistor in the grid circuit is used most often in generators which operate with self-excitation. The bias resistor in the cathode circuit is used in generators with independent excitation (amplifiers). In the latter case, bias produced by anode current prevents a possible excess in the anode current (dangerous for the tube) under the conditions when generation is interrupted or the tube in the preceding stage becomes inoperative. Sometimes both forms of automatic bias are employed simultaneously. /194

The so-called two-stage generator circuit is widely employed in practice. A highly simplified two-stage circuit (Fig. 178) looks like a double one-tube circuit (see Fig. 168), but with

one common oscillator circuit (L_a, C_a) and a coupling grid coil (L_g). The power supply is connected to the center tap of the circuit coil and to a common point for the cathodes of the two tubes. As in the case of the one-stage generator, the oscillations which arise in the anode circuit pass through the coupling coil to produce varying potentials on the tube grids. The potentials on the grid of each tube are opposite in phase (shifted by 180°). This causes a phase shift by 180° between the oscillations of the anode currents of the tubes, which pass through each half of the circuit coil. As they pass through the circuit coil, the anode currents of the tubes suppress the current of the oscillator process, which thus retains a constant value and the oscillations have a nondamping character. Hence, the oscillations in the circuit are subject to the influence of the anode current in the tubes twice during each period of oscillation. The circuit is therefore called a two-stage circuit.

Self-excitation of a two-stage generator by connecting a voltage source is produced by an insignificant difference in the characteristics of the tubes or by a lack of symmetry in the two halves of the circuit, as well as by unavoidable fluctuations of the current in the tubes. The difference between the currents which pass simultaneously through the two tubes creates a voltage drop across the circuit coil, so that the capacitor charges. This begins the oscillations during which alternating potentials are created on the tube grids, which suppress further operation of the generator. /195

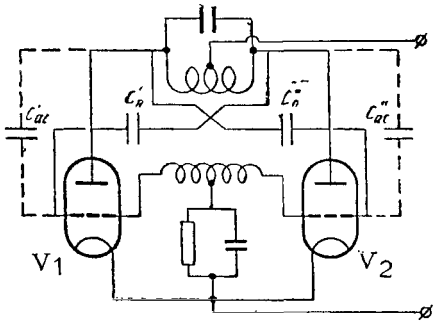


Fig. 180. Principle of Neutralization in a Two-Stage Generator With Independent Excitation.

A vacuum-tube generator with independent excitation is often used as a high-frequency amplifier with an oscillator circuit included in the anode circuit (Fig. 179, a - one stage; 179, b - two-stage circuit). An amplifier of this kind is called a resonance amplifier.

The operation of a generator with independent excitation is analogous to that of a generator with self-excitation, with the exception of the fact that it lacks feedback to the grid. In a generator with independent excitation, the tube grid receives oscillations from an independent source which is called the master generator or exciter and operates with self-excitation. These oscillations control the anode current of the tube, producing and suppressing the oscillations in the anode circuit of the generator. Therefore, everything which was mentioned earlier with respect to the method of powering a generator

can also be applied to a generator with independent excitation: the methods of applying the bias to the grid, the values of the interelectrode capacitances, etc.

Generators with independent excitation use special devices for suppressing the self-excitation of parasitic oscillations at frequencies which are considerably different from the nominal value. The most common means of doing this are: the use of tubes with a screen grid (see below), the shielding of individual connections and circuits, the inclusion of antiparasitic resistors in the proper circuits, connecting separating filters in specific circuits, and finally, using a two-stage circuit with neutralization by means of neutrodyne capacitors.

Screening of the grid and anode circuits considerably reduces the parasitic links of inductive and capacitive type, which can be produced between the circuits. Connecting antiparasitic resistors in the anode and grid circuits increases the damping in these circuits and therefore resists self-excitation. Separating filters sharply limit the passage of high-frequency oscillations from one circuit to the next, which usually produces self-excitation of parasitic oscillations.

So-called neutralization is an effective means of suppressing parasitic self-excitation in the output stage of a generator. In many cases, neutralization (even at ultrahigh frequencies) makes it possible to use simpler tubes for the output stage; triodes can be used, regardless of the fact that the transient capacitance of a triode is much greater than that of a tetrode or pentode. The achievement of neutralization is facilitated considerably in a two-stage cascade circuit.

The principle of neutralization operates as follows; an additional circuit containing a low-value capacitor (neutrodyne capacitor) supplies an alternating potential to the grid of the tube; this is called the compensating ("neutralizing") potential, and is formed as a result of a capacitive link with the anode of the tube. In the most widely employed two-stage circuit, neutralization is accomplished by connecting two capacitors, connecting the anodes and grids of the tubes, connected in different arms of the circuit (Fig. 180). /196

In Figure 180, the dashed line represents the capacitive link between the grid of tube V_1 and its anode (capacitor C_{ac}), so that an alternating high-frequency potential is produced on the grid which is capable of producing and suppressing the process of self-excitation. The alternating potential from the other end of the oscillator circuit passes through capacitor C_n, called the neutrodyne, to the grid; this potential is of opposite phase. Therefore, these potentials neutralize one another. In order to ensure optimum neutralization conditions, capacitor C_n has a variable capacitor whose value is adjusted to its final value

when setting up the apparatus for use.

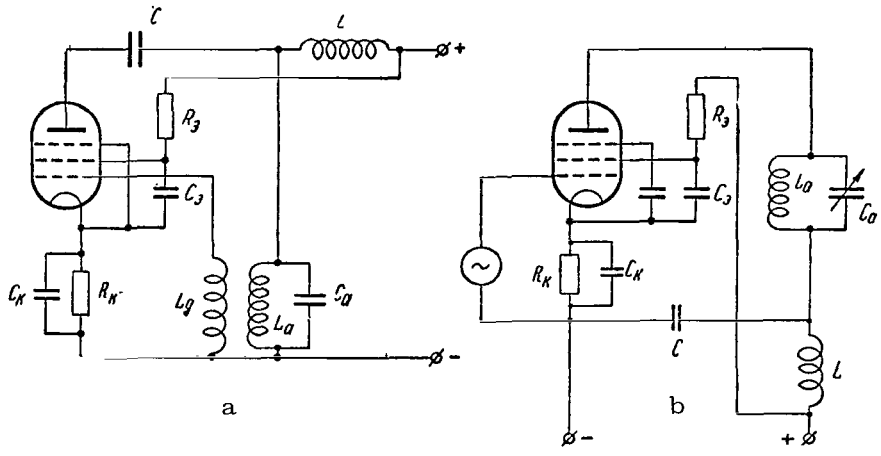


Fig. 181. Schematic Diagram Showing Connection of a Screening and a Shielding Grid in a Tube. a. In a Generator With Self-Excitation and Parallel Power Supply; b. A Generator With Independent Excitation and Series Power.

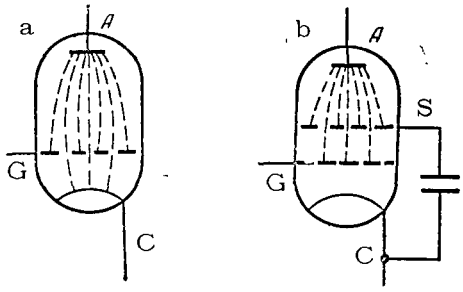


Fig. 182. Arrangement of Lines of Force of a High-Frequency Field. a. In a Triode; b. In a Tube With a Screen Grid.

In addition to triodes, beam tetrodes and pentodes can also be used as generator tubes. Figure 181 is a schematic representation of the use of screen and shield grids: (a) in a generator with self-excitation and a parallel power supply, and (b) in a generator with independent excitation and a series power supply.

A constant positive voltage which is smaller than that on the anode is usually found on the screen grid. In many cases, a change in the voltage on the screen grid is used to regulate the power of the generator. At high frequencies, the screen grid is connected to the cathode through a capacitor which reduces the transient capacitance of the tube (this is extremely important for generators with independent excitation, in which the capacitance between the anode and the grid produces an undesirable feedback). The screen grid, connected to the cathode by a capacitor of sufficient

/197

value, assumes the potential of the cathode at high frequencies, so that a large part of the lines of force of the electrical field travel only between the anode and the screen grid, and do not reach the control grid. The capacitance between the anode and the grid then drops considerably. Figure 182 is a schematic representation of the arrangement of the lines of force of an electrical field between the anode, grid, and cathode: (a) in a triode and (b) in a tube with a screen grid.

In pentodes, the screen grid is either connectly directly to the cathode (Fig. 181) or else through a capacitor, if an independent voltage is applied to it.

§3. STABILIZATION OF FREQUENCY AND SUPPRESSION OF RADIO INTERFERENCE

High-frequency electrical apparatus used for therapeutic purposes often acts as a generator of electrical oscillations. Similar generators are used for radio communications. The difference between the latter and the medical generators lies only in the manner in which the oscillations are employed. In the first case, the generator is connected to an antenna which serves as a device for achieving the maximum possible radiation of the electromagnetic wave through space; in the second case, the generator is fitted with electrodes which transfer the oscillations to the object being treated, where they are absorbed.

However, the operation of medical generators also produces a slight radiation of electromagnetic waves. This is because the electrodes and the wires connecting them to the apparatus and even the patient himself constitute portions of an oscillator circuit and are not separated from the surrounding environment by any kind of screen. Particularly intense radiation of electromagnetic waves takes place when performing UHF treatment with large gaps between the electrodes.

Radiations in the space surrounding the parts of the high-frequency portion of the generator, the electrodes and wires, or the patient himself produce electromagnetic waves which are picked up by radio receivers and television sets, disturbing their proper operation. For this reason, they are called radio interferences.

Radio interference can be propagated "through the ether" in all directions, or along the electrical wires in the wall ("through the line"). The intensity of the radio interference propagated through the ether depends on the level of the voltage which the radiation of these interferences produces on the receiving antenna of a special device used for this purpose, called the interference meter. This voltage is called the level of the field of radio interference and is measured in μV.

The intensity of the radio interference propagated "through the line", is measured by the level of the voltage which it produces at the terminals of a noise source or at any other point in the electrical circuit which is connected to the noise source. This voltage is called the voltage level of the radio interference and is measured in μV.

The interference meter is a highly sensitive superheterodyne radio receiver, fitted with the proper inputs. An apparatus of type IP-12 (Fig. 183) is used to measure frequencies from 0.15 to 20 MHz, and is fitted with an antenna mast 1 m high. The type IP-14 instrument is used for measurements in the range from 20 to 150 MHz, and is fitted with an antenna consisting of a half-wave dipole. To measure interference in the line, the terminals of the type IP-12 instrument are fitted with a shielded coaxial cable containing a capacitor, equivalent to the antenna; the IP-14 instrument is fitted with a special device connected to the input of the instrument. /198

In conjunction with today's broad development and considerable importance of radio communication and television, government regulations have limited the permissible levels for radio interference from all electrical and technical devices, including medical apparatus. This is of special importance for high-frequency electrical medical apparatus.

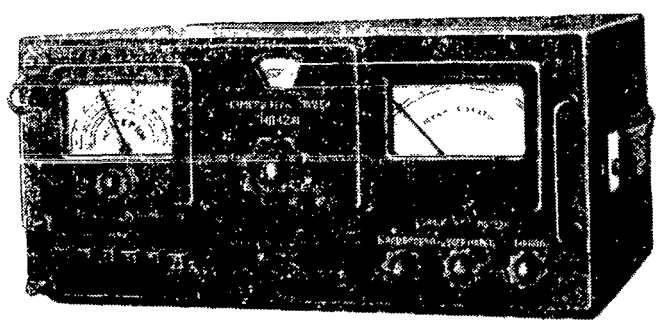


Fig. 183. Overall View of Instrument for Measuring Radio Interference (IP-12).

A measure which has facilitated the problem of dealing with radio interference has been the production of certain types of apparatus (in this case, medical high-frequency generators of certain frequencies, at which radio communications devices do not operate). Radio interference is not standardized for these frequencies or else exceeds the permissible norms by a considerable degree.

The following are excerpts from the "All-Union Standards for Permissible Industrial Radio Interference", issued in 1962.

The following dates are established for introducing the present All-Union Standards for Permissible Industrial Radio Interference:

July 1, 1963 for newly planned, developed and produced electrical and radio equipment, apparatus, assemblies, and mechanisms (with the exception of those cases discussed in the appendices to the Table of Standards);

January 1, 1967, for electrical and radio equipment, apparatus, and assemblies and mechanisms, currently in use and made before July 1, 1963.

All ministries, departments, Councils of National Economy, and other organizations are instructed to proceed in accordance with the present All-Union Standards for Permissible Industrial Radio Interference during the period up to January 1, 1967; this applies to all electrical and radio equipment, assemblies, mechanisms and other devices currently in use and developed up to July 1, 1963.

The standards for permissible industrial radio interference are extended to radio interference produced by electrical devices, equipment, and apparatus for different purposes operating in the 0.15-400 MHz range and lasting longer than 1 sec. /199

The intensity of the interference and the compliance of the source with the requirements of the standard must be determined by the following:

Field of interference at a given (standard) distance from the interference source;

Interference voltage as detected at the terminals of an interference source or an interference-transmitting line.

The permissible levels for the interference field and interference voltage must not exceed the values given in the table of standards. For high-frequency instruments for medical and scientific applications (operating at frequencies which do not fall into the ranges defined) used in residences or connected to the household electrical wiring, must fall within the following levels (Table 19).

Thirteen frequencies have been set aside for apparatus used for scientific and medical purposes; these frequencies are divided into three subgroups on the basis of the emission conditions and the use of these instruments:

TABLE 19

Permissible Level of the Radio Interference Field, in μV					Permissible Voltage Level of Radio Interference, in μV				
In Subranges of MHz Frequency					In Subranges of MHz Frequency				
from 0.15 to 0.5	from 0.5 to 2.5	from 2.5 to 20	from 20 to 400	measurement conditions	from 0.15 to 0.5	from 0.5 to 2.5	from 2.5 to 20	from 20 to 400	measurement conditions
100	50	20	50	at a distance of 10 m from the instrument	250	100	50	-	at a distance of 10 m from the instrument

A. Frequencies which can be used in the absence of undesired interference to radio communications prior to the development of standards for industrial interference [1]; these are divided into the following frequency bands: 22 kHz ± 7.5% and 66 kHz + 12 and -10%.

B. Frequencies which can be used under the conditions when the level of the radio interference field from the high-frequency installation at a distance of 150 m will not exceed 200 μVV:

440 kHz ± 2.5 %	1760 kHz ± 2.5%
880 kHz ± 1.0 %	5280 kHz ± 2.5%

C. Frequencies which can be used if no undesirable interference is caused to radio communications devices, which are subdivided into these frequency bands:

13,560 kHz ± 0.05%	152.5 MHz ± 1%
27,120 kHz ± 0.6 %	460 MHz ± 1%
40,680 kHz ± 2.0 %	2375 MHz ± 2%
	22,135 MHz ± 0.5%

In conjunction with the above, we have supplied Table 20 to show how these frequencies are distributed over the methods of high-frequency electrical therapy.

[1] The range of frequencies below 0.15 MHz (Author's Note).

Let us turn now to discussion of the means employed in combating radio interference (some of them are called means "for shielding" against radio interference). In the first place, all high-frequency apparatus without exception, both that which is operational and that which has been rebuilt, must be registered at the local office of the State Electrical Communications Inspector. /200

TABLE 20

Frequency	Method	Frequency	Method
440 kHz	D'arsonvalization	40.68 MHz	UHF Therapy
880 kHz	(ultrasound)	152.5 MHz	-
1760 kHz	Diathermy		Microwave Therapy
5280 kHz	-	460 MHz	(decimeter)
13,560 kHz	Inductothermy	2375 MHz	(centimeter)
27,120 kHz	-	22,125 MHz	-

At the present time, all high-frequency medical apparatus is either produced in a form which is completely "shielded" from radio interference and can therefore be used under ordinary conditions, or else the factory which is producing the apparatus provides information regarding special conditions for its use, e.g., regarding the need for using in a shielded chamber.

Special blocking filters are used to limit radio interference propagated "along the line"; they operate by retarding the propagation of oscillations. The filters consist of chokes connected in series and capacitors connected parallel to them, whose inductances and capacitances are suitably calculated according to the power of the apparatus and the frequency of the oscillations which are generated. Such filters are used in all mass produced high-frequency apparatus (and in low-frequency apparatus in cases where it is required).

A shielded chamber is used to weaken the radio interference produced by high-frequency apparatus so that it is below the permissible operating standards. Any electrotherapeutic apparatus can be used in the chamber, which is powered by 127 or 220 VAC and does not draw more than 2500 VA.

The chamber is intended for use with any of the following instruments: (a) the device for pulsed UHF therapy; (b) the apparatus for UHF therapy operating at 300 W power; (c) vacuum-tube apparatus for UHF therapy, inductothermy and diathermy, which do not operate at a certain frequency (e.g., foreign-made apparatus); (d) spark apparatus for therapeutic diathermy or for local d'arsonvalization.

The overall dimensions of the chamber are 2180 × 2280 × 2660 mm. The chamber weighs 400 kg.

The shielded chamber (Fig. 184, a is an exterior view; Fig. 184, b is a view showing the door open) serves as a housing for the apparatus and the patient, being closed on all sides by a fine brass screen which is grounded and serves as a good conductor of electrical current; this is used as a shield. The electromagnetic waves formed within the chamber when the apparatus is operated strike the screen and are partially reflected from it back into the chamber and partially absorbed in it, creating eddy currents. As a result, the field produced outside the limits of the chamber has an intensity which does not exceed the permissible level.

For suppressing noises which are propagated along the line, the input to the chamber is fitted with an electrical filter which is mounted outside on top of the chamber.

The chamber is made of thin wooden panels covered with brass screening. The boards are joined by bolts to form the walls, floor and door of the chamber. For improved electrical contact, the edge of the door is covered by a hollow rubber tube, connected to the brass screen. At the top of the door, which is located /201 in the front wall of the chamber, there is a window for observing the patient; it is also covered with brass screening. The joints between the walls and floor are covered by baseboards painted with red lead, which prevents them from being soaked with water when the floor of the chamber is mopped. The floor of the chamber is covered with linoleum, and the walls are covered with veneer up to 1.8 m above the floor.

A fan is located inside the chamber. The fan switch is located at the top of the left-hand side wall of the chamber. On the rear wall, a plate with a socket and switch is provided for plugging in the apparatus (apparatus which uses current up to 6 A may be plugged into the socket); a light switch for illuminating the chamber is also provided. The latter consists of two ceiling fixtures with incandescent lights.

The schematic diagram of the electrical apparatus in the chamber is shown in Figure 185. In the figure we have the following: C - transient capacitor KBP-F; 1 μf, 220 V, 40 A; L - high-frequency choke with iron core; 1, 1, a-switch; 2 - electric fan; 3 - noise-suppressing filter; 4, 4 a - I-27 fuse with insert for 30 A; 5 - socket for 220 V, 6 A; 6 - ground clamp; 7 - three-pole switch; 8, 8 a - incandescent lamps; 220 V, 100 W. The chamber is provided by the factory for operation on 220 V. If the chamber is to be used with 127 V, the fan, fuses, and illuminating lamps must be replaced.

The door of the chamber must be completely shut when oper-

ating apparatus inside. The patient is observed through the window. If mechanical damage or wear should necessitate removal of a portion of the brass screen, a new piece should be cut from the supply provided with the chamber. This piece should be of the same size and shape as the damaged area, and should be placed over it and fastened by weaving a thin wire around its perimeter to join it to the surrounding intact screen. The patch should be soldered all around its perimeter.

Fig. 184. Shielded Chamber. (a) External View; (b) View With Door Open.

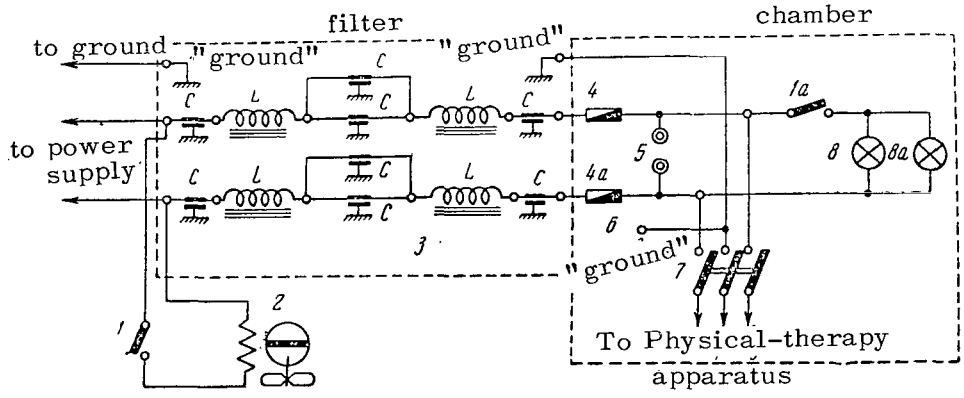


Fig. 185. Schematic Diagram of Electrical Apparatus in Shielded Chamber.

In order to ensure compliance with the required standards for combating radio interference in places where medical gener-

ators are operated, special measures are taken to stabilize the frequencies of these generators and keep them within the required limits. In the case of particularly narrow permissible limits for frequency variation, such as 13,560 kHz ± 0.05%, e.g., generators are used which are equipped with quartz frequency stabilizers.

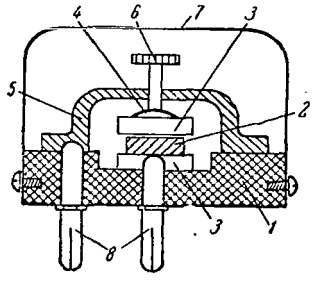


Fig. 186.

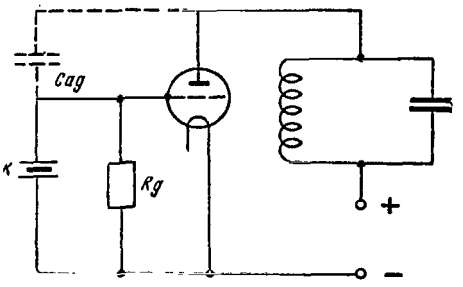


Fig. 187.

Fig. 186. Diagram of Quartz Stabilizer.

Fig. 187. Schematic Diagram for Connecting Quartz Frequency Stabilizer.

The quartz stabilizer (Fig. 186) consists of a disk 2, cut in a special manner from quartz crystal and placed between metal clamps 3, which serve as electrodes. The quartz disk, along with its electrodes, is placed on an insulated base 1 and held in place by means of a spring 4, a frame 5 and a tightening screw 6. The entire assembly is mounted inside a housing 7. At the bottom, on the base 1, are two prongs 8 which provide electrical contact with the electrodes of the quartz. The prongs are used to plug the stabilizer into a socket provided at the proper point in the generator circuit. The natural frequency of the quartz stabilizer depends on the dimensions of the quartz disk. The quartz stabilizer is usually connected into the circuit for the control grid of a tube (Fig. 187) and replaces the grid oscillator circuit. Thanks to the high Q-factor of quartz, the latter is generally able to provide the proper oscillation frequency for the generator.

If the frequency of the anode circuit of the generator shows a tendency to change, then thanks to the properties of the quartz which enable it to change its equivalent resistance in response to very small changes in oscillator frequency, this tendency does not undergo further development and the frequency of the generator remains constant. A stability of the generator frequency, which can be achieved with the aid of the quartz, is very high. /203
Only a generator of very low power (usually on the order of several watts) can be stabilized directly by means of a quartz crys-

tal. If it is necessary to obtain considerable power from the generator, such as that required, e.g., by an apparatus for diathermy (200-250 V), then the stabilized oscillations of the master generator must be amplified by one or two stages.

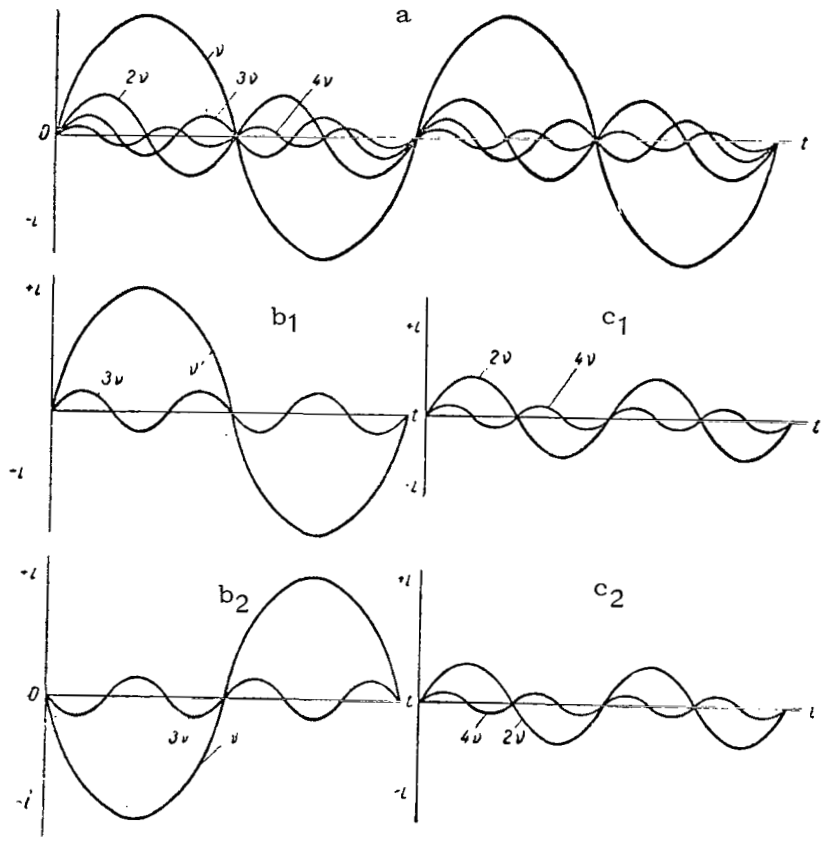


Fig. 188. Graph of the Oscillations of the Basic Frequency and the Upper Harmonics (a), and With a Half-Period Shift of the Basic Frequency (b,c).

In concluding this section, we should also note that a two-stage circuit for the output stage has several advantages over a one-stage circuit, with respect to suppression of radio interference, as well in regard to facilitating the shielding of the power supply from high-frequency oscillations. This is related to the fact that in a two-stage generator the even harmonic oscillations are not transmitted from the anode circuit to the load (therapeutic circuit), while the oscillations of both the basic frequency and the odd harmonics are not transmitted from the anode circuit to the power supply.

Let us look at this question in more detail. Earlier, in discussing the circuit of a simple amplifier, it was pointed out that the oscillations in the anode current double the oscillations of the potential on the grid only under the conditions when the tube is operating within the limits of the straight line portion of the tube characteristic (Class A regime). Generators use more /204
economical regimes (Classes B and C), in which the oscillations of the anode current have a complex form which differs from the sinusoidal oscillations of the potential on the grid. These complex oscillations of the anode current, according to the Fourier theorem, can be represented as the sum of the constant component and the sinusoidal oscillations with frequencies which are multiples of the basic frequency of the oscillations in question: ν, 2ν, 3ν, 4ν, etc. (see Fig. 188, a, in which the graphs of the oscillations of the basic frequency as well as the second, third, and fourth harmonics are compared).

The result of the division of the anode currents of the tube into various parts of the circuit of a two-stage generator depends on both the voltage and the phase ratio between these currents.

In a two-stage generator, the anode currents of the tubes are shifted in time by a half period of the basic frequency. Correspondingly, a shift by a half period is found in the basic and all odd harmonics, which are then in opposite phase (see Fig. 188, b_1 and b_2, in which the graphs of the basic and third harmonics of two complex oscillations are compared, shifted by a half period and in opposite phase). This means that all odd harmonics are shifted by a full period and are therefore in phase (Fig. 188, c_1 and c_2).

In the oscillator circuit, the anode currents of the tubes pass through both halves of the coil in opposite directions. Therefore, the effect of the even harmonic oscillations, which coincide in phase and direction, will cancel one another out.

The anode currents of the tubes are combined in a common power lead; consequently, both the oscillations of the basic frequency and the odd harmonics of the oscillation which are in opposite phases will cancel one another out.

The mutual cancellation of the harmonic oscillations is more complete as the oscillations of the anode currents in the two generator tubes coincide more exactly in value and shape, i.e., the greater the degree of symmetry of the circuit, the greater the mutual annihilation of the harmonic oscillations.

PART 3

APPARATUS FOR DIATHERMY

§1. UNIVERSAL APPARATUS FOR DIATHERMY (UDL-350)

After production of spark apparatus was suspended, the Union Factory of the EMA produced a vacuum-tube apparatus for therapeutic diathermy (DTL-2) with generator tubes GK-71 (old designation G-471). The apparatus was not provided with protective devices to shield against radio interference, and this limited the possibility of its use; at the present time it is practically not used at all. In 1949, the VNIIMIO developed a new stationary apparatus intended for use both as a therapeutic and surgical diathermy apparatus. It was therefore called the "universal apparatus for diathermy". The apparatus had a power of approximately 400 W, operated on a selected frequency of 1625 kHz, and was equipped with a quartz stabilizer, in 1951, the factory produced the first series of these instruments. During their use, it was found that less power was required for therapeutic processes, and that a smoother method of regulation was required. Therefore the EMA Factory, in 1952, reduced the total power of the apparatus to 350 W, made it possible to adjust the power in two stages of 150 and 350 W, and also made several changes in the electronics circuitry. /205 This apparatus was called the UDL-350 (universal vacuum-tube diathermy apparatus).

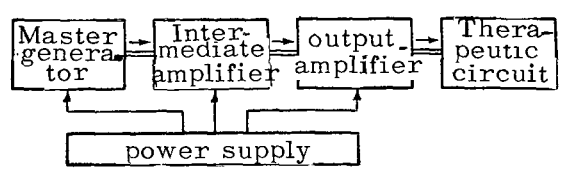


Fig. 189. Block Diagram of Universal Apparatus for Diathermy (UDL-350).

The UDL-350 is a three-stage generator of electrical oscillations at high frequency, with quartz stabilization. The basic frequency of the generator is 1625 ± 0.8 kHz.

The nominal power of the generator is 350 W. The apparatus has two power stages: 350 ± 50 W with an active resistor of 80 Ω acting as a load, and 150 + 50 W using an active resistor of 200 Ω as a load.

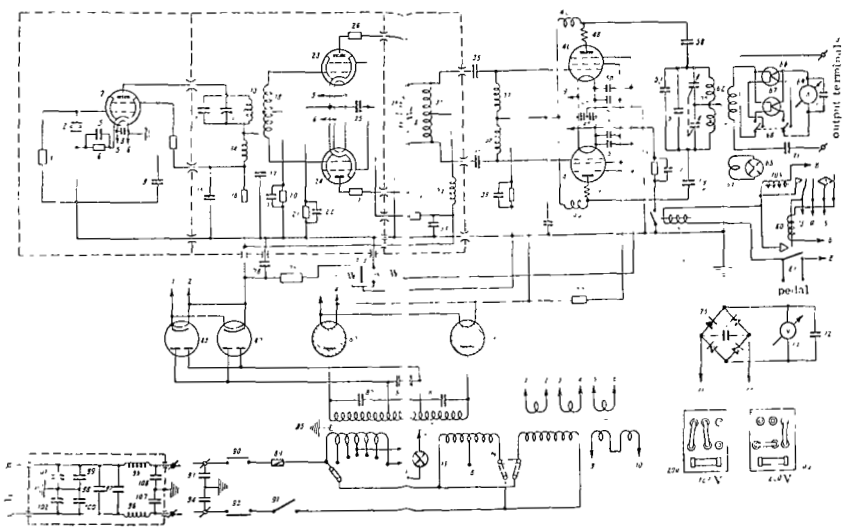


Fig. 190. Schematic Diagram of Universal Apparatus for Diathermy. (UDL-350).

The output power of the two stages can be adjusted smoothly from zero to the maximum. Using the reduced power setting and the active resistor of 200 Ω as a load, the current in the patient's circuit at the ninth setting of the regulator does not exceed 0.65 A. Thus, the current which is drawn from the circuit is 12 A at 127 V and 7 A at 220 V.

The block diagram of the apparatus (Fig. 189) consists of five parts: (1) master generator; (2) intermediate amplifier; (3) output amplifier; (4) therapeutic circuit; (5) power supply.

The complete schematic diagram of the UDL-350 apparatus is shown in Figure 190. The master generator uses a 6PZ tube (represented by 7 in the circuit, with a quartz stabilized frequency). The quartz stabilizer 2 is connected between the control grid and the cathode of the tube. The frequency of the natural oscillations of the quartz is 1625 kHz. The connection between the anode and the grid circuits is accomplished by the interelectrode capacitance of the tube (anode-grid). The bias on the control grid is produced by resistor 6, which is connected to the cathode circuit of the tube and is blocked by capacitor 5, by means of leak resistor 1 connected in the circuit of the control grid. The constant current component of the control grid in various tubes may differ somewhat, not exceeding 0.15 mA; the portion of the bias produced by this current amounts to about 15 V. The constant current component on the cathode is on the order of 30 mA, and the other part of the bias produced by this current is 25 V. The total bias voltage is about 40 V.

The amplitude of the exciting voltage (high frequency) on the control grid does not exceed 37 V.

The voltage on the screen grid of the tube is on the order of 160 V and is produced by quenching resistor 10; the current in the screen grid is 2-2.4 mA; the screen grid is linked at high frequency to the cathode by capacitor 9.

The anode circuit of the master generator consists of coil 13 and a capacitor which consists of two capacitors connected in parallel, one fixed 11 and one adjustable 12. The resonant frequency of the circuit is 1625 kHz.

The anode circuit is powered by a kenotron rectifier through resistor 16 and high-frequency coil 14, blocked by capacitor 15. The power is fed to the center tap of coil 13, which is grounded for high frequency by capacitor 17. This is necessary in order to make the changeover from a one-stage circuit in the master generator to the symmetrical two-stage circuit of the intermediate amplifier, the voltage on whose grid must be in opposite phase.

A voltage of 310 V appears on the anode of the tube. The constant component of the anode current is about 30 mA.

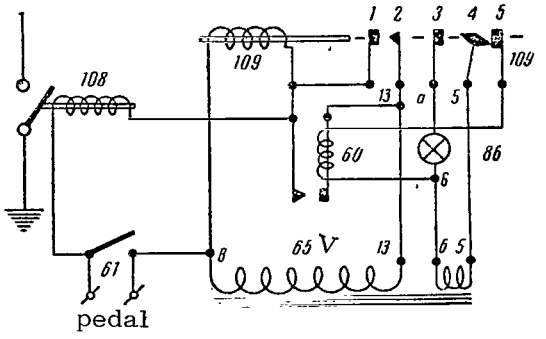


Fig. 191. Schematic Diagram of Relay Block in the UDL-350 Apparatus.

The intermediate amplifier /206 consists of a two-stage circuit using 6PZ tubes (23 and 24). There is an inductive coupling with the master generator; the circuit coil 18 is connected to the control grids of the tubes. The bias on the control grids is produced by resistors 21 and 20, which are connected to the cathode and grid circuits of the tubes, respectively, and are blocked by capacitors 22 and 19. The magnitude of the bias which is produced by the anode current is on the order of 16-24 V, while that produced by the grid current is on the order of 20-25 V, thus amounting to a total of 40-45 V. The combined bias produced by the grid and the anode currents makes it necessary on the one hand, to stabilize the operation of the generator, which to a large degree is produced by the bias from the grid current, and on the other hand, to prevent the possibility of a sharp rise in anode current in the tubes in the case of an interruption of the exciting voltage being fed to them (e.g., if the quartz stabilizer should fail). The increase in current in this case produces a corresponding increase in the bias (due to the resistance in the cathode circuit), which resists a further increase in the anode current.

The constant component of the grid current (two tubes) is 4-5 mA. The amplitude of the exciting voltage of the amplifier is 40-50 V (between the grids of the two tubes).

The voltage on the screen grids of the tubes is on the order of 250-300 V and is produced by quenching resistor 32. The current of the screen grids of the two tubes is about 16 mA without a load and 24 mA with a full load. The grids are joined to the cathodes by capacitor 25 at high frequencies.

The anode circuit consists of coil 31 and a capacitor formed by a group of capacitors connected in parallel: two fixed capacitors 29 and 30 and an adjustable one 28. The midpoint of the capacitors 29 and 30 is grounded to ensure symmetrical excitation of the output amplifier. The anode circuits of the tubes contain "antiparasitic" resistors 26 and 27. The anode circuit is set to a frequency of 1625 kHz.

The anode circuits are powered by a kenotron rectifier through coil 34, blocked by capacitor 33. A voltage of 380 V is applied

to the anodes of the tubes. A constant component of the anode current of the two tubes is about 130 mA without a load and 105 mA with a full load.

The output amplifier uses a two-stage circuit with GK-71 tubes (46 and 47). The connection with the intermediate amplifier is made through separating capacitors 35 and 36. The bias on the grids is produced by resistors 56 and 40, which are connected to the cathode and grid circuits of the tubes, respectively, and blocked by capacitors 57 and 39, while the bias is applied to the grids by blocking coils 37 and 38.

The portion of the bias produced by the resistance in the cathode circuit is about 30 V when the amplifier is operating without a load and about 50-65 V under full load; the other part, produced by the resistance in the grid circuit, is about 25 V regardless of the amplifier regime.

The constant component of the grid circuit (two tubes) is 70-75 mA. The amplitude of the exciting voltage of the amplifier is about 370 V (between the grids of the two tubes).

The voltage on the screen grids comes from the gas-filled rectifier tube to resistor 77. The magnitude of the voltage is about 150 V without a load and 150 V with a full load. The current on the screen grids (two tubes) is 70-80 mA. The screen grids are connected to the cathodes by capacitors 51 and 51′ at high frequency. /207

The shielding (antidynatron) grids of the tubes, depending on the power level of the apparatus, are switched by control 103 either to the "minus" of the circuit (the regime of reduced power 150 W), or through resistor 76 to the kenotron rectifier (full-power regime, 350 W). In the latter case, a voltage on the order of 40 V is placed on the grids without a load and it is 100 V with a full load. The current on the shielding grids (two tubes) is 15-17 mA without a load and 12-14 mA with a full load.

At high frequency, the shielding grids are connected to the cathodes by capacitors 50 and 50′.

The anode circuit is set to a frequency of 1625 kHz and consists of coil 62 and a capacitor element made up of the following capacitors connected in parallel: fixed capacitors 52 and 53 and variable capacitor 104. The center taps of the circuit coil 62 and the variable capacitor 104 are grounded. Antiparasitic resistors 48 and 49 are connected to the anode circuits of the tubes.

The power for the tube anodes comes from a gas-filled rectifier tube through high-frequency chokes 42 and 43, which are blocked by capacitor 41; the oscillator circuit is shielded from

the direct current by separating capacitors 58 and 59. The filament wires of the high-frequency tubes are grounded through capacitors 44 and 45.

A voltage on the order of 1300 V is applied to the tube anode. The constant component of the anode current (two tubes) is about 200 mA without load and 500 mA in a full-power regime.

The therapeutic circuit consists of capacitor 71 and movable circuit coil 63, which is located inside coil 62. Regulation of the output power is accomplished by changing the connection between the coils, rotating the axis of the movable coil. By using switch 68, thermocouples 66 or 67 of the measuring apparatus can be connected to the circuit. The measuring device is an ammeter 69, which has two measurement ranges: 0-1 A and 0-3.6 A. The apparatus is blocked by capacitor 70. The maximum high-frequency voltage at the output terminals of the apparatus with a load is about 200 V.

The filament 64 of tube 65 is connected to the coil of the anode circuit, signaling the presence of high-frequency oscillations in the circuit.

The apparatus provides for screening of the following units:
(a) the master generator (without the anode oscillator circuit);
(b) the intermediate amplifier (without the anode oscillator circuit), along with the anode oscillator circuit of the master generator;
(c) the oscillator circuit of the intermediate amplifier, connected to the grid circuit of the output amplifier.

The output amplifier, along with the therapeutic circuit, is shielded by the cabinet of the apparatus.

The power for the generator comes from a power transformer 85 and two rectifiers, which operate in a full cycle arrangement: one of these is the gas-filled tube rectifier consisting of two VG-129 tubes (79 and 80) and a kenotron rectifier using two 5Ts4S tubes (87 and 88) connected in parallel. The rectifier with the gas-filled tubes does not have a ripple filter and feeds the anodes and screen grids of the tubes in the output stage; the rectifier with the kenotrons has a capacitor 78 which smooths out the pulsations and feeds the master generator, the intermediate amplifier, and the antidynatron grids of the tubes in the output amplifier. /208

The power for the anode circuits of the tubes in the output amplifier comes from the closed contacts of relay 108. The latter only operates when switch 61 is turned on (provided that the intermediate relay 109, which conducts the power to the coil of relay 108, has operated first).

The power transformer has the following windings:

(a) Two wires for connecting the apparatus to the power line (127 or 220 V).

(b) A winding for the voltage compensator, which ensures normal operation with changes in the power line within limits from 95 to 130 V (when connected to 127 V) and from 190 to 225 V (when connected to 220 V).

(c) Filament windings which provide a voltage of 20 V (for powering the GK-71 tubes), 6.3 V (for powering the 6P3 tubes), 5 V (for the 5Ts4S kenotrons) and 2.5 V (for the gas-filled tubes VG-129).

(d) A step up winding whose outer leads power the gas-filled tube and whose inner leads power the kenotron rectifier.

The high-voltage section of the transformer windings is blocked by capacitors 81-84.

From the voltage compensator, leads run to voltmeter 73, which is connected through selenium rectifier 75.

The primary winding of the power transformer is connected to contacts 90 and 92 of interlocks which are located on the removable sides of the cabinet; this circuit also contains switch 91 for the power supply and a fuse 89.

To reduce radio interference, the apparatus is provided with a filter which consists of two chokes 95 and 96 and capacitors 97-102 and 106-107, which are contained in a separate unit. The power cord which runs from the apparatus to the filter is shielded.

The filter is fitted with a clamp for grounding. Two wires run from the filter and are fitted with clips for attaching them to the terminals on the power unit.

The apparatus operates as follows. When the apparatus is plugged into the line, the line voltage through the compensator reaches the primary winding of the power transformer 85. Power for heating all the tubes comes from the filament windings of the transformer, both for the generator portion and the power supply consisting of gas-filled tubes and kenotrons. After several seconds, which are required for the kenotrons to heat up, the voltage is transmitted to the anodes of the master generator and the intermediate amplifier, as well as to the protective grids of the output tubes.

When the power voltage is being supplied, the master generator is excited and oscillations with a frequency of 1625 kHz appear in its anode circuit, to which the latter is set. The mutual induction between coils 13 and 18 in the control grids of the tubes of the intermediate amplifier there is a voltage which

produces more powerful oscillations of the same frequency in the anode circuit, which is set to a frequency of 1625 kHz. The exciting voltage passes to the control grids of the tubes in the output amplifier through separating capacitors 35 and 36.

The high voltage is then turned on to power the anodes and the screen grids of the output amplifier. This is accomplished by means of a relay block (see Figs. 190 and 191), whose operation is as follows. When the apparatus is switched on, the voltage from the heater windings of the power transformer, which has a value of 6.3 V, passes through the closed contacts 4 and 5 of the intermediate relay 109 to reach the heating element of the time-delay relay 60. After 3-5 min, which are required for the /209
element to heat up the element, the time-delay relay operates. A bimetallic strip, located inside the heating element, bends and the contact on its tip closes the circuit to the coil of intermediate relay 109, which is powered for an additional tap (65 V) on one of the line windings of the transformer. The intermediate relay operates and changes the connections as follows: it opens contacts 4 and 5 (the circuit to the thermal relay), closes contacts 4 and 3 (the circuit to pilot light 86), closes contacts 1 and 2 (the circuit for powering intermediate relay 109 and relay 108, closing the high-voltage circuit). Now, in order for relay 108 to operate, it is sufficient to close the circuit to it by switch 61, located on the control panel of the apparatus, or by using a pedal.

This position, indicating the readiness of the apparatus for switching on the high voltage from the gas-filled tube rectifier to the output amplifier, is indicated by the lighting up of the left-hand (white) pilot light 86.

When switch 61 is closed or the contacts of the pedal are closed, relay 108 operates and a high voltage is transmitted to the anodes and screen grids of the output amplifier. Oscillations of considerable power and voltage then appear in the anode circuit, at a frequency of 1625 kHz (to which this circuit is also set). The apparatus is ready for use. This position of the circuit is signaled by the illumination of the right-hand pilot light 65.

From the anode circuit of the output amplifier, thanks to the mutual induction between coils 62 and 63, the oscillations reach the therapeutic circuit and the electrodes attached to the patient. The power of the oscillations in the therapeutic circuit is regulated by changing the connections between coils 62 and 63, which is accomplished by moving adjustable coil 63 with respect to the other (fixed) coil 62.

The data on the schematic diagram are listed below in the specifications.

It should be mentioned that short-circuiting the high voltage supplied to the output tubes on the cathode side is highly undesirable from the standpoint of safe operation: when the apparatus is connected to the line, the parts will be at a high positive potential relative to the chassis. This makes it difficult to make adjustments inside the apparatus and to correct the operation of individual circuits when adjusting or correcting defects.

Specifications for the Schematic Diagram of the UDL-350 Apparatus.

1	Resistor VS-1; 100 kΩ ± 10%
2	Quartz Stabilizer; frequency equals 1625 kHz
5	Capacitor KBGI; 0.01 μf, 400 V
6	Resistor VS-2; 680 Ω
7	Vacuum Tube 6PZ
8-9	Capacitor KBGI; 400 V, 0.01 μf
10	Resistor VS-2; 68 kΩ
11	Capacitor KSO-6; 1000 V, 330 μμf
12	Variable capacitor KPK-2; 25-150 μμf
13	Induction coil 25.5 μh
14	High-frequency choke 2-3 mh, PShD wire, 0.25 mm in diameter, wound on a coil. Approximately 80 m long.
15	Capacitor KBGM-1; 400 V, 0.01 μf
16	Resistor PE-I, 2000 Ω
17, 19, 22	Capacitor KBGM-1; 400 V, 0.01 μf
18	Circuit coil 23 μh
20	Resistor VS-1; 5.1 kΩ
21	Resistor PE-I; 150 Ω
23-24	Vacuum tube 6PZ
25	Capacitor KBGI; 400 V, 0.01 μf
26-27	Resistor VS-2; 33 Ω
28	Variable capacitor
29-30	Capacitor KSO-12; 3000 V, 910 μμf
31	Induction coil, 15 μh
32	Resistor PE-II; 5000 Ω
33	Capacitor KBGI; 400 V, 0.01 μf
34	High-frequency choke, 2-3 mh (see Item 14)
35-36	Capacitor KSO-11; 2000 V, 2000 μμf
37-38	High-frequency coil 2-3 mh (see Item 14)
39	Capacitor KBGM-1; 400 V, 0.01 μf
40	Resistor PE-1; 250 Ω
41	Capacitor KSO-12; 2000 V, 3300 μμf
42-43	High-frequency coil, 3 mh (PBD wire, 0.41 mm in diameter, wound on a coil. Approximately 800 turns)
44-45	Capacitor KBGI; 400 V, 0.01 μf
46-47	GK-71 Vacuum tube
48-49	Wire-wound resistor; 1.6 Ω
50-50[1]	Capacitor KSO-12; 2000 V, 3300 μμf
51-51[1]	Capacitor KSO-12; 2000 V, 3300 μμf
52-53	Air-gap capacitor, 185 μμf

56	Resistor PE-111; 100 Ω
57	Capacitor KBG-1; 400 V, 0.01 μf
58-59	Capacitor KSO-13; 5000 V, 1800 μμf
60	Time Relay
61	Switch (toggle)
62	Induction coil, 26 μh
63	Circuit coil, 4 μh
64	Connector
65	Pilot light 6.3 V, 0.28 A
66	Thermocouple, 1 A
67	Thermocouple, 3.6 A
68	Switch
69	Thermoammeter, PTM-70
70,72	Capacitor KSO-5; 500 V, 5100 μμf
71	Capacitor KSO-11; 3000 V, 820 μμf
73	Voltmeter PM-70; 0-20 V
74	Capacitor KSO-5; 500 V, 5100 μμf
75	Selenium rectifier; VS 18-13
76	Resistor VS-5; 20 kΩ
77	Resistor PE-IV; 15 kΩ
78	Capacitor KBG-MN; 600 V, 4 μf
79-80	Gas-filled rectifier, VG-129
81-84	Capacitor KSO-13; 2000 V, 10,000 μμf
85	Power transformer
86	Pilot light, 6.3 V, 0.28 A
87-88	Vacuum tube 5Ts4S
89	Fuse KN-20 a (or 10 a)
90,92	Block
91	Switch PK-2
93-94	Capacitor KBG-M1; 400 V, 0.1 μf
95-96	Filter choke, 40 μh
97	Capacitor KBGI; 400 V, 0.05 μf
98	Capacitor KSO-11; 500 V, 10,000 μμf
99-100	Capacitor KBGI; 400 V, 0.05 μf
101-102	Capacitor KSO-11; 500 V, 10,000 μμf
103	Switch (toggle)
104	Variable capacitor, 2 x (25:70) μμf
106-107	Capacitor KSO-5, Group "b", 500 V, 5100 μμf
108	High-voltage relay
109	Intermediate relay

The general design of the UDL-350 apparatus is described below. The apparatus is mounted in a metal cabinet, fitted with four casters and two handles for convenience in moving.

The overall dimensions of the cabinet are 530 × 420 × 960 mm; it weighs 90 kg.

The front and back panels of the cabinet can be removed; they are held in place by screws and fitted with interlocks which disconnect the apparatus from the line voltage when the panels are removed.

/21

The following equipment is mounted on the control panel of the apparatus (Fig. 192): at the upper left is voltmeter 9 for indicating the supply voltage, and to the right of it is ammeter 10 for the patient's circuit. Between these instruments is toggle switch 4, which turns on the high voltage, and below it is switch 5 for the heating elements of the ammeter. Below the measuring devices are pilot lamps 7 and 8; between them and somewhat below is toggle switch 3 which adjusts the power stages.

At the bottom left is knob 2 for the voltage compensator, and in the center is knob 6 for the power regulator; at the right is switch 1 for the power supply.

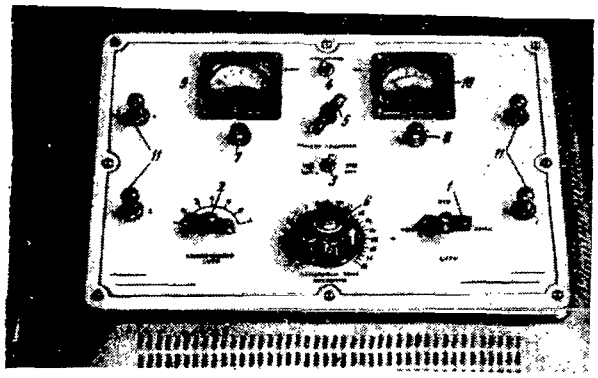


Fig. 192. Location of Parts on the Control Panel of the UDL-350 Apparatus.

On the right-hand and left-hand sides of the control panel are terminals 11 for connecting the wires from the electrodes leading to the patient. The apparatus is intended for treating one patient at a time.

The parts of the electrical circuit are mounted in individual units and located inside the cabinet on three shelves. On the bottom shelf is the power transformer, the power supply, and the relay block; the second shelf holds the master generator, intermediate amplifier, and tubes of the output amplifier; on the top shelf are the remaining parts of the output amplifier, the anode oscillator circuit and parts of the therapeutic circuit.

Figures 193 and 194 show a general view of the apparatus with the front and back of the cabinet removed. When the front of the cabinet is removed, the parts located on the top and bottom shelves are visible; the middle shelf is covered by a screen

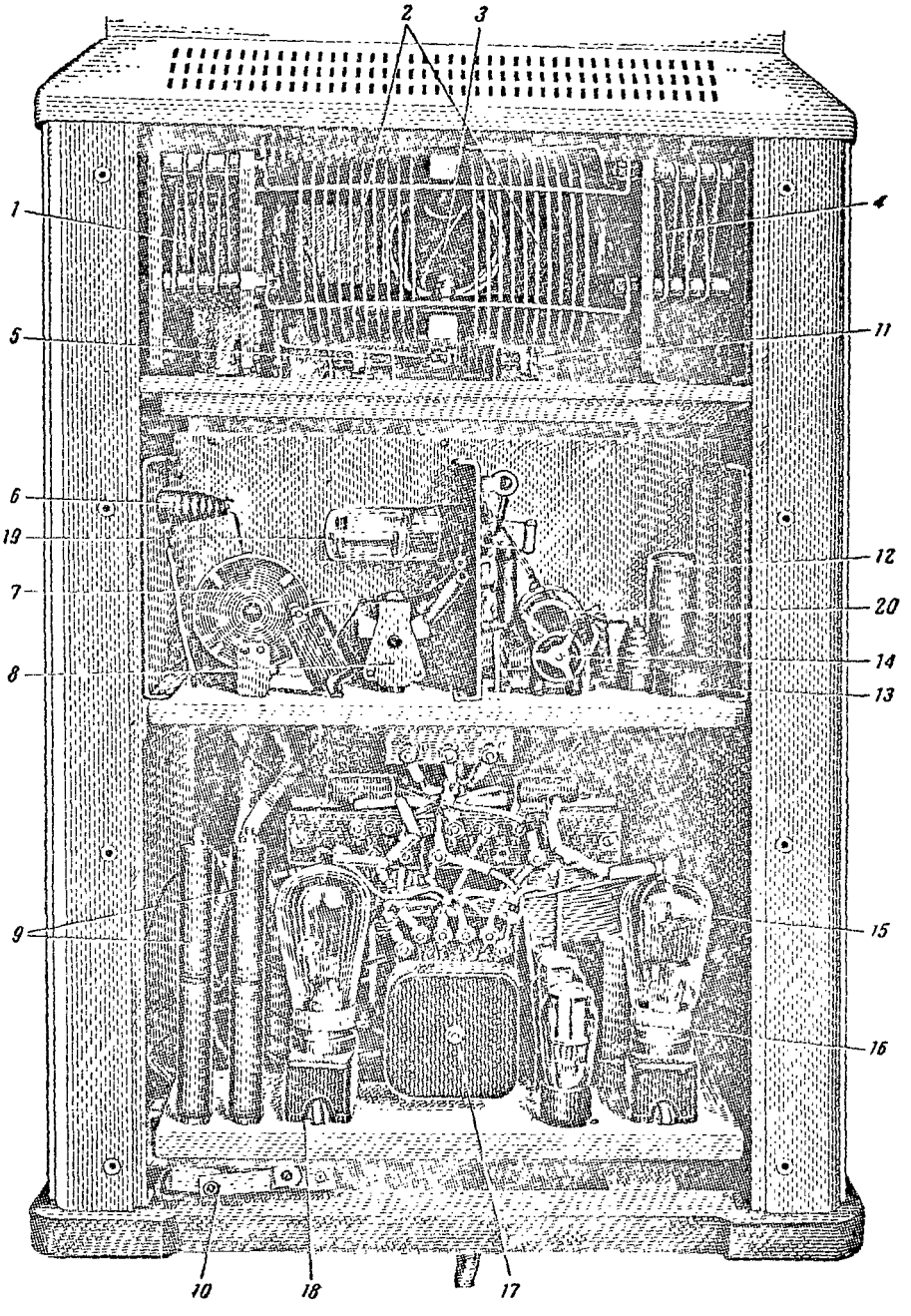


Fig. 193. Location of Parts in the UDL-350 Apparatus; View With the Front of the Cabinet and Screen Removed.

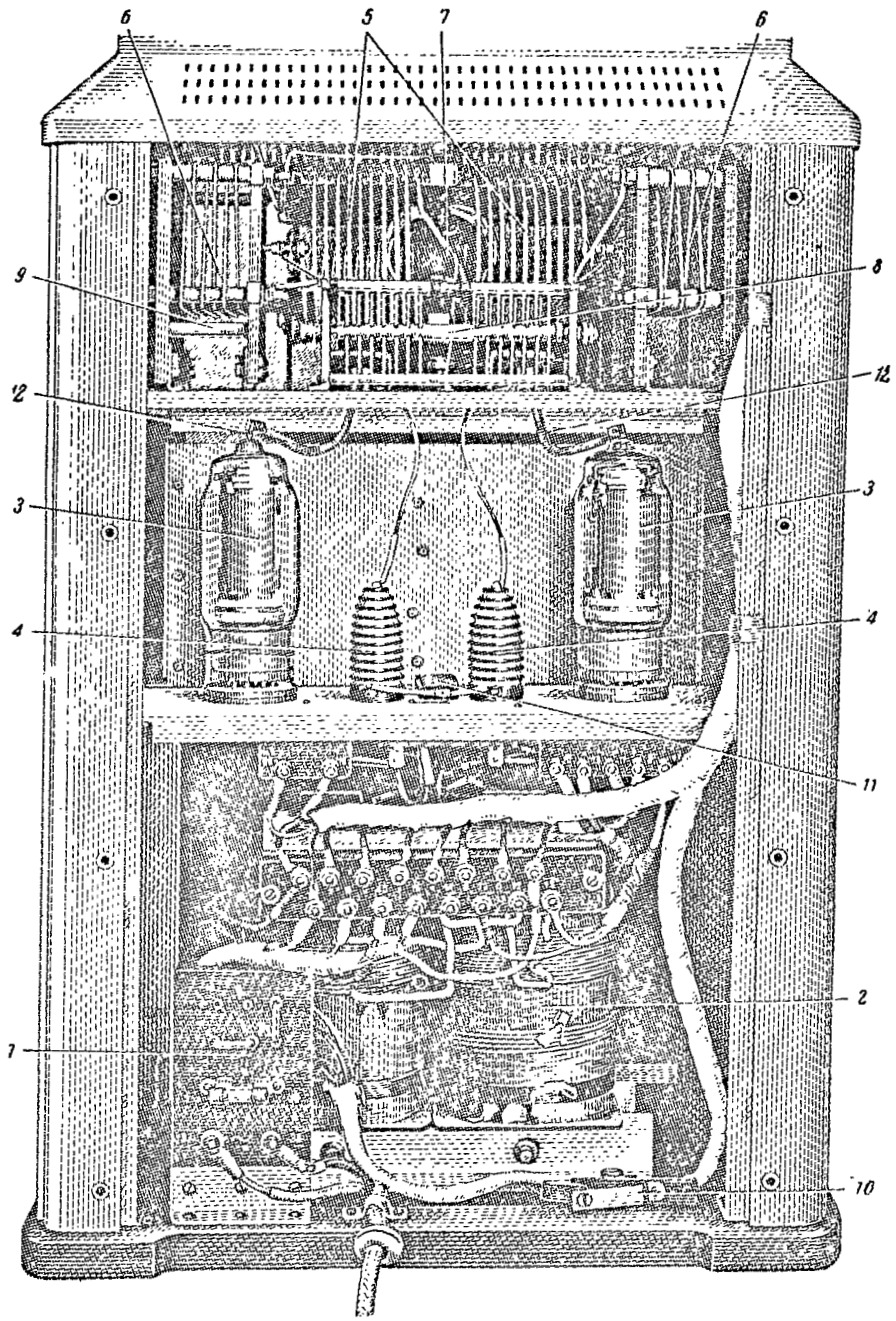


Fig. 194. Location of Parts in the UDL-350 Apparatus; View With the Back of the Cabinet Removed.

held in place by three screws at the top and three screws on the bottom.

To remove the screen, the bottom screws are removed and the top ones loosened slightly; the screen can then be slid to the right and lifted off the heads of the upper screws.

There are two openings in the screen: one is of rather small diameter (at the left), and another is located at the right. Through these holes it is possible to adjust the variable capacitors: the right-hand hole gives access to the anode circuit of the master generator, while the left-hand hole provides access to the anode circuit of the intermediate amplifier. After the screen is removed, it is possible to reach the parts which are located on the middle shelf, as shown in Figure 193.

On the bottom shelf in the middle is the power transformer. /214
A terminal strip is attached to the top of its core; wires run from this to various parts of the system. In front of and below the transformer is the closed black box 17 containing the relays, which include two electromagnetic relays, basic and intermediate (represented by 108 and 109 on the schematic) and a thermal relay for allowing the gas-filled rectifier tubes to heat up.

To the right of the relay box are two kenotrons 16 and one gas-filled rectifier 15; behind them is a capacitor (marked 78 in the circuit). To the left of the relay box is a second gas-filled rectifier 18 and to the left of that a group of vitreous resistors 9 (marked 77 in the circuit).

Below the panel forming the front of the block are the wires from the rectifiers. To the left and below are the contacts 10 of the interlock.

The middle shelf contains two closed metal screens and various shielded compartments. In the right-hand one is the anode circuit of the master generator, while the left-hand one contains the anode circuit of the intermediate amplifier; the lower part of the chassis of the right-hand compartment serves as the third shielded compartment, containing the remaining parts of the master generator.

In the compartment for the master generator is the 6P3 tube (12) and in front of it the quartz crystal 13. Further to the left in the center, mounted on a conical support is the choke (marked 14 in the circuit) and behind it (on the back of the compartment) is a capacitor (marked 17 in the circuit).

On the left-hand side of the compartment are coils 20 mounted on two cylindrical supports. On the inner support is the coil for the anode circuit of the master generator (marked 13 in the circuit). The capacitors of the circuit are connected in parallel

with the leads of the coil: these include the ceramic disk capacitor 14 and parallel to it the mica fixed capacitor of type KSO (marked 12 and 11 in the circuit). Capacitor 14 is adjusted by means of a Bakelite tube with three notches.

The outer support carries the coil for the grid circuit of the intermediate amplifier (marked 18 in the circuit). The leads from this run to the barrier between the shelves, which serves as a chassis for the intermediate amplifier. Tube panels are located on the chassis, as well as capacitors and resistors.

The connecting wires of the master generator, as well as the remaining parts of the latter are mounted on the lower part of the bottom of the shelf, which serves as a chassis.

In the left-hand compartment, at the right, two tubes 6P3 (19) from the intermediate amplifier are located on the partition; below them is an air-gap adjustable capacitor 8 in the anode oscillator circuit (marked 28 in the circuit). The handle of the capacitor extends forward and is fitted with a plastic knob with a slit below the usual opening. By turning the knob, the value of the capacitor can be changed to tune the oscillator circuit.

To the left of the capacitor is coil 7 of the anode oscillator circuit of the intermediate amplifier (marked 31 in the circuit), and the end terminals of the latter are connected to the capacitors of fixed value in the oscillator circuit of KSO type (marked 29 and 30 in the circuit). The anode voltage reaches the middle of the coil through a high-frequency choke located to the left of the separator (marked 34 in the circuit). Its blocking capacitor (marked 33 in the circuit) is located below the horizontal separator.

Behind the compartments containing the master generator and intermediate amplifier is the output amplifier. The connection from the intermediate amplifier to the output amplifier is accomplished by means of wires which run below the chassis. The leads /21
from coil 7 run through the separating capacitors of type KSO (marked 35 and 36 in the circuit) to the sockets on the panel for the amplifier tubes. Below the chassis are two small high-frequency chokes (marked 37 and 38 in the circuit) which block the bias circuit for the grid.

The compartment for the output amplifier can be seen when the back of the cabinet is removed (Fig. 194). On the sides of it are two GK-71 tubes (3), and between them are two chokes 4 in the power circuit to the anodes (marked 42 and 43 in the circuit); in the exact center is blocking capacitor 11 (marked 41 in the circuit). Coils of wire 12 are connected to the anodes; they serve as antiparasitic resistors (marked 48 and 49 in the circuit).

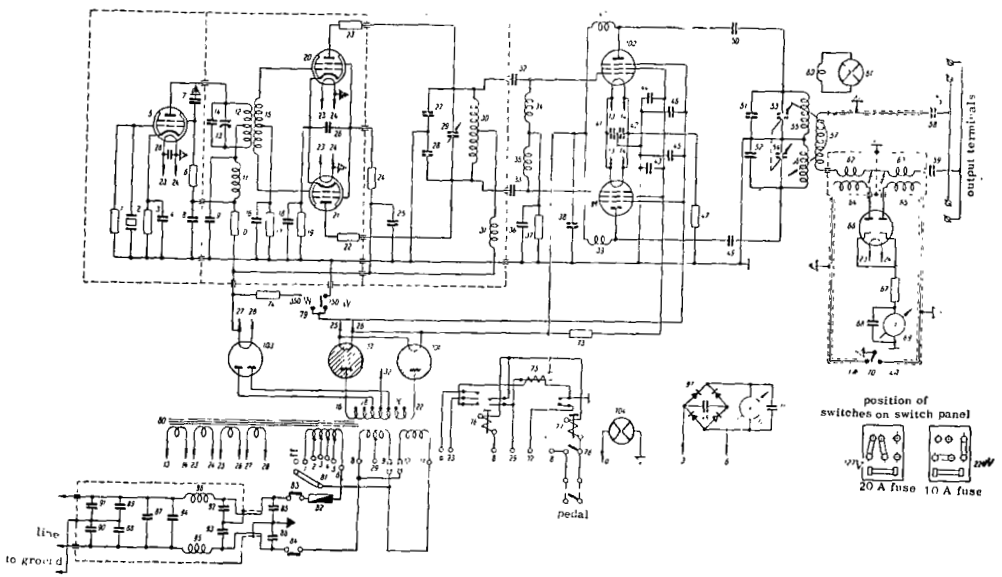


Fig. 195. Schematic Diagram of UDL-350M.

Coil 2 in the anode circuit of the output amplifier is located on the upper shelf and can be seen better from the front of the apparatus (Fig. 193).

The coil consists of two parts wound on strips. Within them, between the sections, is coil 3 of the therapeutic circuit, mounted on adjustable strips. Beside the coil are two sections of an air gap capacitor [1 and 4 of constant value, part of the anode oscillator circuit (marked 52 and 53 in the circuit).]. Behind them (Fig. 194) is adjustable air-gap capacitor 8 in the anode oscillator circuit (marked 104 in the circuit). The handle for the rotor of the capacitor extends to the left and has a plastic knob with a slit. By turning the knob, the value of the capacitor can be changed and the circuit "tuned". For convenience in adjustment, a round hole has been made in the left-hand side of the cabinet. A long screwdriver can be inserted into this hole; it passes through a guide bushing 9, made specially for it in the bottom of the left-hand side of the air-gap capacitor 6 in the anode oscillator circuit. Behind capacitor 8 are the inductance coils 5 and 7 of the anode and therapeutic circuits.

In the center, below the coil (Fig. 193) are separating capacitors 5 and 11 (type KSO), arranged symmettrically into groups (marked 58 and 59 in the circuit). The capacitor in the therapeutic circuit is of type KSO (marked 71 in the circuit), and is located at the bottom of the control panel near the left-hand output terminals.

On the back of the cabinet, at the bottom, is a window closed by a removable lid; through this window it is possible to switch the circuit to the suitable line voltage (127 or 220 V) and also to replace the fuse.

In the general view of the apparatus with the back cover of the cabinet removed (Fig. 194), we can see on the lower shelf the power transformer 2, above it the terminal strip, to the left panel 1 with fuses and contacts for switching the circuit to the proper line voltage, and at the bottom right the contacts 10 of the interlock.

On the bottom of the control panel are the following: the high-voltage switch and the switch for voltage compensation, as well as the reducing gear for the power regulating knob. The reducing gear ensures that a rotation of the coil through 90° is produced by moving the knob through 300°. The design of the operating parts of the reducing mechanism permits a quite smooth and gradual increase of current when the knob for power regulation is turned.

On the bottom of the left-hand side of the cabinet are the contacts for connecting the pedal, which is employed when the apparatus is used for surgical procedures.

The capacitors in the oscillator circuits are not adjusted during normal operation; it may be occasionally necessary to adjust them in case there is some difficulty with normal operation (interruption in generation, burning out of anodes, insufficient power, etc.). In any case, adjustment is necessary whenever parts of the circuit are replaced or adjusted.

The apparatus is used as follows. Before plugging the apparatus into the line, it is necessary to ensure that all the control knobs are set to the starting position: the switches must be in the "off" position, the knob of the circuit compensator must be in position 1. The current regulator knob must be in position 0, and the knob for switching the heating elements must be in the position "3.6 A". /216

The apparatus is then plugged into the wall. The line switch on the control panel of the apparatus is thrown to the "on" position. The pointer on the left-hand dial (voltmeter) should then be deflected somewhat. The knob of the voltage compensator is then turned to the right until the voltmeter pointer reaches the red line. Depending on the desired current intensity, the switch for setting the power level is set to 150 W or 350 W.

Several minutes after the power is turned on, the relay operates to produce the delay required for the gas-filled rectifier tubes to heat up; the left-hand pilot light lights up to show that the apparatus is ready for the high voltage to be switched on. The toggle switch is then thrown, which allows high voltage to flow into the circuits; the right-hand pilot light then lights up.

By smoothly turning the regulator knob for current intensity clockwise, the current is brought to the desired level, as indicated by the right-hand meter (ammeter). Initially, by using the instrument scale on 3.6 A, the current is set somewhat lower than the desired value, since the first minutes of operation may see the resistance of the patient's skin change somewhat, so that the current will increase; after several minutes, the current is set to its final value.

The apparatus can then be switched to the 1 A scale if necessary. (To protect the thermal elements, the scale selector switch should be set to 3.6 A before turning on the current.)

When treatment is complete, the regulator knob for the current is smoothly rotated to the zero position and the high voltage is shut off (by the switch). It is only then that the electrodes can be removed from the patient. If the treatments are being given in a series, the apparatus need not be disconnected from the line (in this case, it is necessary to examine the voltmeter periodically and make corresponding changes in the supply voltage).

When all the treatments are complete, the voltage compensator knob must be reset to position 1, the power supply must be turned off, and the plug should be pulled from the wall as well.

For surgical diathermy, the apparatus is fitted with an additional pedal (the toggle switch which controls the high voltage then remains fixed in the "off" position). The apparatus is then turned on as described above (until the high voltage is turned on).

The high voltage is turned on and off by means of the pedal. The required setting for the current is adjusted each time by smoothly rotating the current-regulator knob after turning on the high voltage (with the pedal) and closing the circuit by touching the active electrode to the tissue. If the electrode is to be changed or the procedures to be altered, the current-regulator knob must first be returned to the zero position.

The apparatus is turned off as described above.

§2. UDL-350M APPARATUS

In 1954, the UDL-350 with two power stages was modernized and received the number UDL-350M. Several changes were incorporated in the schematic, the equipment was increased and several other changes were made in the general appearance of the instrument.

The Schematic diagram of the UDL-350M appears in Figure 195. /217
The most important change in the electrical portion of the apparatus is the shielding of the wires in the therapeutic circuit within the apparatus and the inclusion in this circuit of a second capacitor. These measures have considerably reduced the emission of radio interference. The method of turning on the high voltage power supply has also been changed: a relay grounds (connects to the chassis) the center tap of the stepup winding of the transformer, which is thereby connected with the common negative for the entire circuit. This method of powering the apparatus was combined with other apparatus (see below).

The UDL-350 M contains a new vacuum-tube meter, an ammeter which is combined with the ammeter from the UDL-200 apparatus. The rectifier which powers the master generator contains one type 5Ts3 tube instead of two type 5Ts4 kenotrons. The line switch is combined with the switch for voltage compensation. The control panel is mounted on a separate unit which is combined with the main assembly by a connecting cable (this makes it easier to gain access to the back of the panel). The position of the output terminals has also been changed, and they have been moved to the back of the apparatus.

Specifications for Schematic Diagram of UDL-350M Apparatus

1	Resistor VS-1; 100 kΩ ± 10%
2	Quartz crystal, 1625 kHz frequency
3	Resistor VS-2; 680Ω ± 10%
4	Capacitor KBGI; 400 V, 0.01 μf ± 20%
5	Vacuum tube 6P3S
6	Resistor VS-2; 68 kΩ ± 10%
7-9	Capacitor KBGI-I; 400 V, 0.01 μf ± 20%
10	Resistor PE-1; 2 kΩ ± 10%
11	High-frequency coil, 2 mh; PShD wire, 0.25 mm in diameter, wound on reel.
12	Induction coil, 2 x 20 turns; PEL-1 wire, 1.25 mm in diameter, inductance 25.5 μh
13	Capacitor KPK-2; 25 ± 150 μμf
14	Capacitor KSO-6; 1000 V, 330 μμf ± 5%
15	Connecting coil, 2 x 8 turns; PEL-1 wire, 1.16 mm in diameter, inductance 23 μh
16	Capacitor KBGI; 400 V, 0.01 μf ± 20%
17	Resistor VS-1; 5.1 kΩ ± 10%
18	Capacitor KBGI; 400 V, 0.01 μf ± 20%
19	Resistor PE-1; 150 Ω ±10%
20-21	Vacuum tube 6P3S
22-23	Resistor VS-2; 33Ω ± 10%
24	Resistor PE-11; 5 kΩ ± 10%
25-26	Capacitor KBGI; 400 V, 0.01 μf ± 20%
27-28	Capacitor KSO-12; 3000 V, 910 μμf ± 5%
29	Variable capacitor
30	Inductance coil, 20 turns; MM wire, 2 mm in diameter, inductance 15 μh
31	High-frequency choke (see Item 11)
32-33	Capacitor KSO-11, 2000 V, 2000 μμf ± 10%
34-35	High-frequency choke (see Item 11)
36	Capacitor KBG-M1; 400 V, 0.01 μf ± 20%
37	Resistor PE-1; 250Ω ± 10%
38	Capacitor KSO-12; 2000 V, 3300 μμf ± 20%
39-40	High-frequency choke 2 mh, PShD wire, 0.4 mm in diameter, wound on reel.
41-42	Capacitor KBGI; 400 V, 0.01 μf ± 20%
43-46	Capacitor KSO-12; 2000 V, 3300 μμf ± 20%
47	Resistor PE-III, 100Ω ± 10%
49-50	Capacitor KSO-13; 5000 V, 1800 μμf ± 20%
51-52	Air-gap capacitor, 350 μμf
53-54	Air-gap variable capacitor, 25-70 μμf
55-56	Inductance coil, 14 turns; MM wire, 2.5 mm in diameter, inductance 44 μh /218
57	Connecting coil, 10 turns; MM wire, 1.88 mm in diameter
58-59	Capacitor KSO-8; 2500 V, 1500 μμf ± 10%
60	Connecting coil, 1 turn; MM wire, 1.5 mm in diameter
61	Incandescent lamp, 3.5 V x 0.28 A

62,64	High-frequency transformer; primary winding 3 turns of PMVG wire, 0.75 cm^2, secondary winding consisting of 140 turns of PShD, 0.25 mm in diameter
63,65	High-frequency transformer; primary winding consisting of 1 turn of PMVG wire, 0.75 cm^2 in cross section, secondary winding consisting of 120 turns of PShD wire, 0.25 mm in diameter
66	Vacuum tube 6Kh6
67	Resistor VS-1; 15 kΩ ± 10%
68	Capacitor KBGI; 600 V, 0.05 μf ± 20%
69	Milliammeter PM-70; 0-5 mA
70	Switch
71	Capacitor KSO-5; 500 V, 5100 μμf ± 10%
72	Voltmeter PM-70, 0-30 V
73	Resistor PE-IV; 15 kΩ ± 10%
74	Resistor VS-5; 20 kΩ ± 10%
75	Thermal relay
76	Time-delay relay
77	High-voltage relay
78	Switch PK-2
79	Toggle switch
80	Power transformer 1200 VA
81	Voltage compensator switch
82	Fuse: 127 V, 20 A or 220 V, 10 A
83,84	Interlock
85-86	Capacitor KBG-M1; 400 V, 0.1 μf ± 20%
87	Capacitor KSO-11; 500 V, 10,000 μμf ± 10%
88-89	Capacitor KBGI; 400 V, 0.05 μf ± 10%
90-91	Capacitor KSO-11; 400 V, 10,000 μμf ± 10%
92-93	Capacitor KSO-5; 500 V, 5100 μμf ± 10%
94	Capacitor KSO-11; 500 V, 10,000 μμf ± 10%
95-96	Filter choke, 40 μh; PBD wire, 2.44 mm in diameter, mounted on reel.
97	Selenium rectifier VS 18-13
98	Capacitor KSO-5; 500 V, 5100 μμf ± 10%
99,100	Vacuum tube GK-71
101,102	Gas-filled rectifier tube VG-129
103	Kenotron 5Ts3S

The apparatus is shipped without tubes installed; it comes with two full sets of vacuum tubes (the regular set and a set of spares), a spare fuse, wires for electrodes, clamps, a set of electrodes (therapeutic or surgical as desired), a technical description and the certificate for the apparatus.

The apparatus is supplied with a set of therapeutic electrodes (Fig. 196, a). There are two hand electrodes 1; foot electrodes for the left side and right side (2 and 3, respectively); large and small rectal electrodes (4 and 5, respectively); medium and small vaginal electrodes (7 and 6, respectively); flexible

lead electrodes 8, measuring 500 × 150 mm (6); handles 9 for the electrodes (2); extensions 10 (2).

The set of surgical electrodes (Fig. 196, b) includes the following: (a) a box 1 with the following: handles (electrode holders) 2 (2); needle electrodes 3 (2); straight knives 4 (2); curved knives 5 (2); loop electrodes 6, 8 mm in diameter, (2); loop electrodes 7, 19 mm in diameter, (2); spherical electrodes 8 (2); disk electrodes 9, 20 mm in diameter, (1); 15 mm (1); 12 mm (1); 4 mm (1); (b) flexible lead electrodes 10, measuring 200 × 150 mm (2); (c) pedal 11.

§3. UNIVERSAL DIATHERMY APPARATUS UDL-200 /219

In 1951-1952, when the UDL-350 apparatus began to be produced, the VNIIMIO together with the EMA Factory devised a universal apparatus for diathermy, operating at a power of 200 W. The basis of this new apparatus was the instrument for surgical diathermy then being produced by the factory ("neurosurgical diathermocoagulator DKN-1M".) The schematic diagram and equipment of this instrument remained unchanged. In order to make it possible to use the full power of the apparatus for prolonged treatment, as well as for therapeutic purposes, a ventilator was provided to ensure adequate ventilation of the electrical equipment.

The nominal data for the UDL-200 apparatus are as follows:

1. Frequency generator operating at 1625 kHz ± 0.05%.

2. Maximum power with active resistor as load, 100 Ω at 200 W. /220

3. The apparatus provides a nominal power with variations in the line voltage between 100 and 135 V (at a nominal voltage of 127 V) and from 200 to 235 V (at a nominal 220 V).

4. The power which the instrument draws from the line at full load is 700 VA.

5. The overall dimensions with the cover closed are 560 × 270 × 410 mm.

6. The apparatus weighs approximately 32 kg.

7. The apparatus is provided with a device for reducing interference with radio receivers.

The schematic diagram of the instrument is shown in Figure 197. It is largely similar to that of the UDL-350 apparatus and consists of five sections: (1) master generator, (2) intermediate amplifier, (3) output amplifier, (4) therapeutic circuit, (5) power supply.

The master generator uses a 6P6 tube (marked 3 in the circuit); the frequency is quartz-stabilized. The quartz crystal (2) is connected between the control grid of the tube and the cathode. The frequency of the natural oscillations of the quartz is 1625 kHz. The connection between the anode and the grid circuits is accomplished by interelectrode (anode-grid) capacitance of the tube. Capacitor 89 is connected to improve this capacitance. Between the grid and the cathode there is a leakage resistor 1. The bias on the control grid is produced in combination with resistor 4, which is connected in the cathode circuit of the tube, and resistor 1. Resistor 4 is blocked by capacitor 5.

The anode circuit of the master generator consists of coil 10 and two capacitors connected in parallel: one fixed capacitor 8 and one variable, 9. The operating frequency of the circuit is 1625 kHz. The anode circuit is connected to the cathode by capacitor 12 for high frequency. The anode circuit is powered from a kenotron rectifier through resistor 7. The power for the screen grid comes through resistor 6, whose grid is connected to the cathode of capacitor 7 for high frequency.

The intermediate amplifier uses a 6P3 tube (18). Connection with the master generator is made through capacitor 13. The bias on the control grid comes from resistor 16 which is connected in the cathode circuit of the tube and blocked by capacitor 17, and leak resistor 15. The grid circuit contains an antiparasitic resistor 14.

The anode circuit consists of coil 26 and some capacitors connected in parallel: two fixed capacitors 22 and 23, and a variable one, 25. At high frequency, the anode circuit is connected to the cathode of the tube by capacitor 21. The anode circuit is operated at a frequency of 1625 kHz.

The power to the anode circuit comes from the kenotron rectifier through a high-frequency choke 24. The power for the screen grid of the tube comes through resistor 20; the grid for high frequency is connected to the cathode by capacitor 19.

The output amplifier is based on a two-stage circuit using G-811 tubes (35 and 36). The connection with the intermediate amplifier is inductive; it is accomplished by connecting coils 27 and 28 and capacitor 37. The oscillations are transmitted to the grid circuit which consists of coil 29, fixed capacitors 31 and 32, and adjustable capacitor 30. The bias on the grids comes from the voltage drop across resistor 38, which is connected to the grid circuit, and resistor 66 which is connected to the cathode circuit of the tubes and shunted by capacitor 67. The control grid circuit contains antiparasitic resistors 33 and 34.

The anode circuit operates at a frequency of 1625 kHz and consists of coil 45 and air-gap capacitors connected in paral-

lel: 42 with a fixed value and double capacitor 41 which has an adjustable value. The rotor knob of the latter is grounded. The /221
circuit incorporates neutralization: between the anodes and the grids of the tubes there are neutrodyne capacitors 39 and 40.

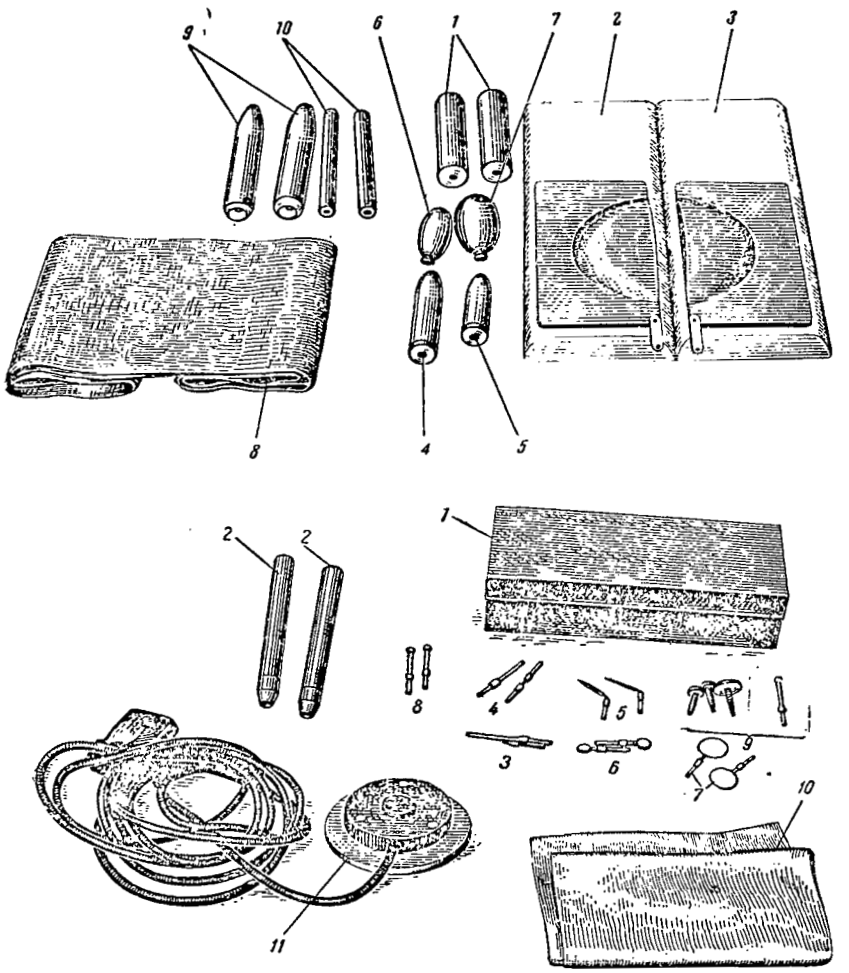


Fig. 196. Sets of Electrodes for Diathermy.
a. Therapeutic; b. Surgical.

The anode circuit is powered from a gas-filled rectifier through choke 55. The coil in the anode circuit is connected by coil 43 to lamp 44 which indicates the appearance of oscillations in the circuit.

The therapeutic circuit consists of an adjustable circuit

coil 46, which is located inside the anode coil 45 and capacitors 47 and 48. The power in the therapeutic circuit is regulated by changing the relationship between coils 46 and 45.

The therapeutic circuit contains a vacuum tube ammeter. This instrument consists of two high-frequency current transformers 49 and 50, kenotron 51, resistor 52, meter 53, blocking capacitor 88, and transformer switch 54.

The anode circuit of the G-811 tube is connected to milliammeter 58, blocking capacitor 57, and in series with them, the contact 64 of the relay which allows the high voltage to flow in the circuit.

By means of pushbutton switch 60, the milliammeter can be connected to the voltage compensator circuit and used to check the supply voltage when regulating the latter.

The apparatus is shielded (in Fig. 197, the shield is represented by a dashed line) for the tubes of the master generator, the intermediate amplifier, and the grid circuit of the output amplifier. The anode circuit of the output amplifier and the therapeutic circuit are shielded by the cabinet of the apparatus.

The generator is powered by a power transformer 72 and two rectifiers which operate on full cycle: a gas-filled rectifier consisting of two VG-9 tubes (VG-129) 67 and 68, and a kenotron using the five Ts4S 71 tube.

The power transformer has the following: (a) two primary windings for connecting the apparatus to 127 or 220 V; (b) a voltage comepnsator winding, which makes it possible to operate the apparatus normally with changes in the power supply voltage within limits from 100 to 135 V (when operating on the 127 V range) and from 200 to 235 V (when operating on 220 V); (c) two filament windings provide a voltage of 6.3 V separately for powering the G-811 tube and the 6P6 and 6P3 tubes; a filament winding which delivers 5 V to power the 5Ts4 kenotron and two windings which deliver 2.5 V, connected in parallel, for powering the VG-9 (VG-129) gas-filled rectifier tubes; (d) a step-up winding whose end leads power the gas-filled rectifiers and whose middle leads power the kenotron rectifier. The primary winding of the power transformer includes a fuse 76 and filter capacitors 74 and 75.

The power supply contains a group of three auxiliary relays. Relay 65 ensures a time delay for warming up the gas-filled rectifiers; when the relay operates, the pilot light 17 on the control panel lights up and the power supply is connected to the coil of intermediate relay 87 and relay 64, which connects the high-voltage circuit (center tap of the step-up winding of the transformer). The circuit including the winding of relay 64 includes the contacts of toggle switch 63, located on the control panel, which is connected in parallel with the contacts of the pedal.

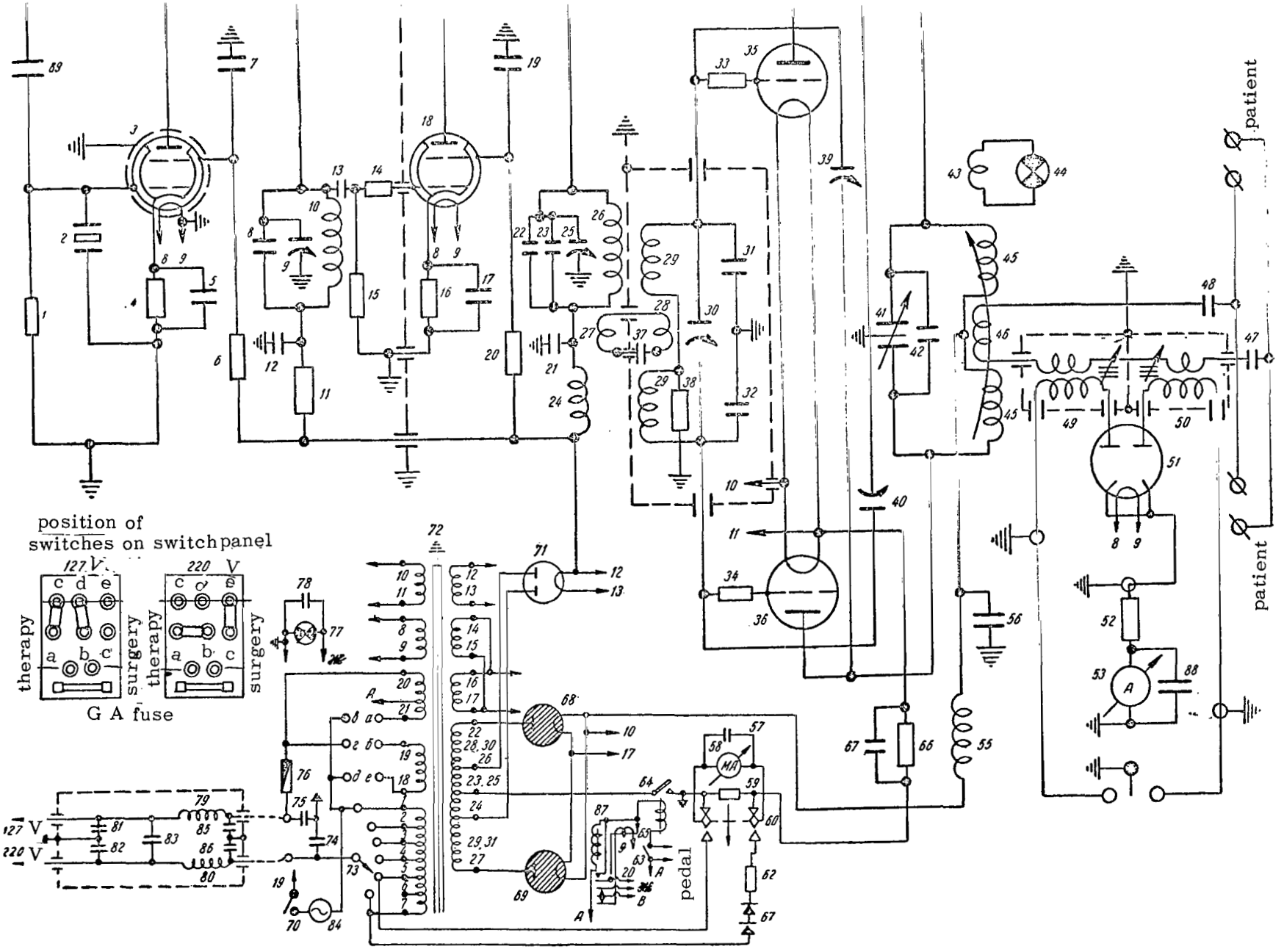


Fig. 197. Schematic Diagram of Universal Diathermy Apparatus UDL-200.

The operation of the relay block is analogous to that of the relay block in the UDL-350 apparatus (see above).

To suppress radio interference propagated over the line, the apparatus is fitted with a filter consisting of two high-frequency chokes 79 and 80 and capacitors 81, 82, 83, 85 and 86.

The electric motor 84 of the ventilator fan is connected to one of the primary windings by means of switch 70.

A wire runs from the voltage compensator section and permits connection of a meter 58 through selenium rectifier 61. /222

Specifications of Schematic Diagram of UDL-200 Apparatus

1 Resistor VS-1; 1 MΩ
2 Quartz crystal, frequency 1625 kHz
3 Vacuum tube 6P6S
4 Resistor VS-2; 430Ω ± 10%
5 Capacitor KBGI; 200 V, 0.05 μf
6 Resistor VS-1; 160 kΩ ± 20%
7 Capacitor KBGI; 400 V, 0.05 μf
8 Capacitor KTK-4; 510 μμf ± 10%, Group D
9 Capacitor KPK-2; 10 ± 100 μμf
10 Coil, 15 μh. PEL wire, 0.64 mm in diameter, 19 turns (wound on coil, 35 mm in diameter)
11 Resistor VS-2; 10 kΩ ± 20%
12 Capacitor KBGI; 400 V, 0.05 μf
13 Capacitor KSO-2; 680 μμf ± 20%
14 Resistor VS-0.25, 750Ω ± 20%
15 Resistor VS-0.5, 390 kΩ ± 20%
16 Resistor VS-2; 255Ω ± 20% (2 × 510Ω connected in parallel)
17 Capacitor KBGI; 200 V, 0.05 μf
18 Vacuum tube 6P3S
19 Capacitor KBGI; 400 V, 0.05 μf
20 Resistor VS-1; 15 kΩ ± 20%
21 Capacitor KBGI; 400 V, 0.05 μf
22 Capacitor KTK-3; 62 μμf
23 Capacitor KTK-4; 200 μμf ± M (two units in parallel) and KTK-4; 150 μμf ± 5% (two units in parallel)
24 High-frequency choke 2.5-4 μh. PShD wire, 0.25 mm in diameter, wound on reel
25 Capacitor KPK-2, 10 ± 100 μμf
26 Inductance coil 15 μh; PEL wire, 1.56 mm in diameter, 22 turns on reel, 40 mm in diameter
27 Connecting coil, PEL wire, 1.56 mm in diameter, 6 turns on reel, 40 mm in diameter
28 Connecting coil, PEL wire, 1.56 mm in diameter, 4 turns on reel, 35 mm in diameter
29 Coil, 75 μh. PEL wire, 0.51 mm in diameter, two sections of 30 turns each wound on reel, 35 mm in diameter

30 Capacitor KPK-2; 10 ± 100 μμf
31-32 Capacitor KTk-4; 150 μμf ± 5%, Group M
33-34 Resistor VS-2; 100Ω ± 20%
35-36 Vacuum tube G-811
37 Capacitor KSO-5, 500 V, 10,000 μμf
38 Resistor VS-2; 1 kΩ ± 10% (2 × 2 kΩ connected in parallel)
39-40 Air-gap capacitor 3 ± 10 μμf
41 Adjustable capacitor (25 + 70) × 2 μμf
42 Air-gap capacitor
43 Connecting coil
44 Incandescent lamp 6.3 V × 0.28 A
45 Induction coil, 65 μh. Wire 2.5 mm in diameter (silver); two sections of 19 turns each, 4 mm between turns; internal diameter of turns, 98 mm
46 Connecting coil, wire 1.88 mm in diameter (silver), 14 turns; 2.5 mm between turns; internal diameter of turns, 58 mm
47-48 Capacitor KSO-8; 1100 μμf ± 10%, Group A
49 High-frequency transformer 3 and 140 turns
50 High-frequency transformer 1 and 120 turns
51 Vacuum tube 6Kh6S
52 Resistor VS-2; 15 kΩ ± 10%
53 Milliammeter PM-70; 0-5 mA
54 Switch
55 High-frequency choke 2.5 ± 4 mh (see Item 24)
56 Capacitor KSO-8; 2500 V, 1100 μμf ± 10%, Group A
57 Capacitor KBGI; 200 V, 0.05 μf
58 Milliammeter MK-55, 0-300 mA /223
59 Shunt for milliammeter
60 Pushbutton switch
61 Selenium rectifier VS 18-60
62 Wire-wound resistor 300Ω
63 Switch
64 High-voltage relay
65 Time-delay relay
66 Resistor VS-2; 50Ω ± 20% (2 × 100Ω in parallel)
67-68 Gas-filled rectifier VG-129
69 Capacitor KBGI; 200 V, 0.05 μf
70 Switch for electric motor
71 Kenotron 5Ts4S
72 Transformer
73 Switch
74-75 Capacitor KBG-M1; 400 V, 0.1 μf
76 Fuse 6 A
77 Incandescent lamp 6.3 V × 0.28 A
78 Capacitor KBGI; 200 V, 0.05 μf
79-80 Choke, 60 μh. PBD wire, 1.56 mm in diameter, 50 turns; wound in the form of a coil with an internal diameter of 18 mm, external diameter of 50-52 mm, and a height of 12 mm (covered with Bakelite enamel)
81-82 Capacitor KBG-M1; 400 V, 0.03 μf

83	Capacitor KBGI; 400 V, 0.05 μf
84	Electric motor DAG-1; 127 V, 21 W
85-86	Capacitor KSO-5; 500 V, 6800 μμf ± 20%
87	Intermediate relay
88	Capacitor KBGI; 200 V, 0.05 μf
89	Capacitor KDK-1; 7 μμf ± 10%, Group D

The following is a general description of the apparatus. As shown in Figure 198, it consists of a metal cabinet with a removable lid which covers the control panel.

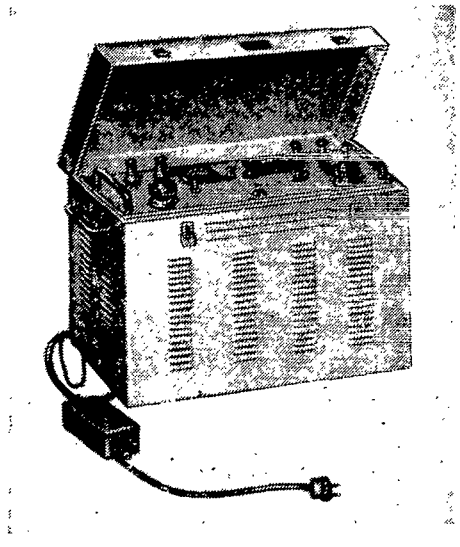


Fig. 198. General View of UDL-200 Apparatus.

A general view of the control panel is shown in Figure 199. The following parts are located on the panel. At the top on both sides are the output terminals 1, while in the middle are two meters: the one on the left is the volt-ammeter 8 and the one on the right is the ammeter for the therapeutic circuit 3. Between these two are the lenses of the pilot lights: the one on the left is pilot light 7 which shows that the time-delay relay is operating while the one on the right is pilot light 2 which indicates that oscillations are occurring in the anode circuit of the output amplifier.

Other parts are as follows: at the left is button 9 for switching the voltmeter "to check the line", while on the right is the ammeter switch 10 for selecting either "1A" or "4A".

On the lower part of the control panel, on the right-hand side, is knob 5 for the power regulator (movable connecting coil), while on the left (in a symmetrical position with the above) is knob 6 for the voltage compensator. In the center is switch 4 for the high voltage.

A general view of the apparatus with the cabinet removed /224
is shown in Figure 200 (front view) and Figure 201 (back view). All parts of the circuit are mounted on a single metal chassis which is removable from the cabinet.

The lower part of the chassis (Fig. 200) contains the power transformer 1. To the left of it are the rectifier tubes: kenotron 2 and gas-filled rectifiers 3 and 4. To the right of the

transformer in a shielded compartment 5 are the parts of the master generator and intermediate amplifier. Above them, in the middle part of the chassis, is the output amplifier. On the front of

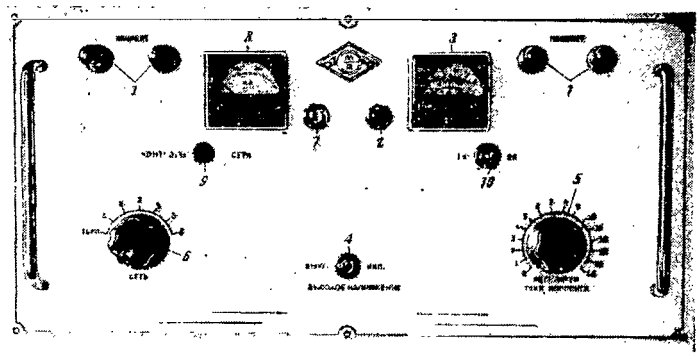


Fig. 199. General View of Control Panel of UDL-200 Apparatus.

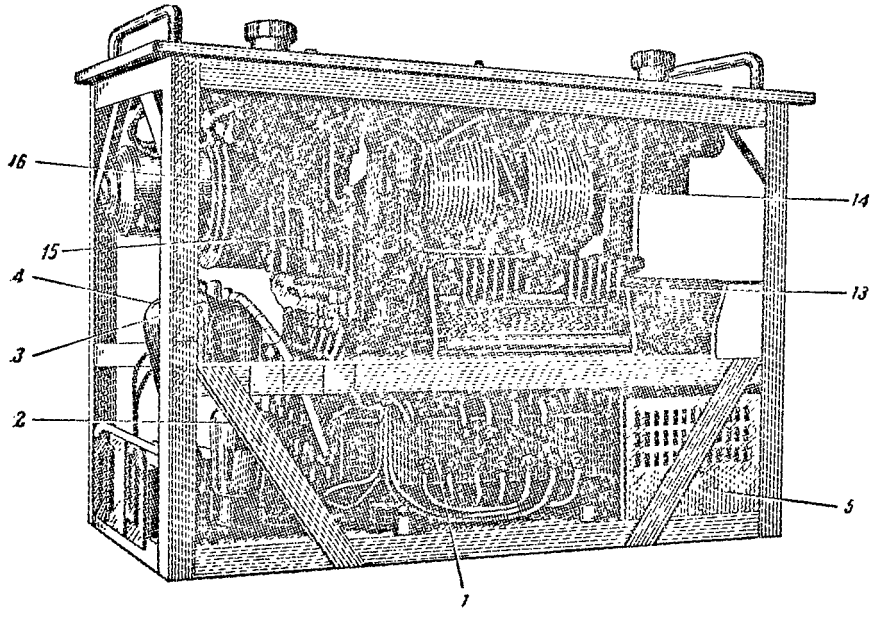


Fig. 200. Location of Parts in the UDL-200 Apparatus (Front View With Cabinet Removed).

the panel is capacitor 13 for the anode circuit. To the left of this capacitor is relay block 15. /22

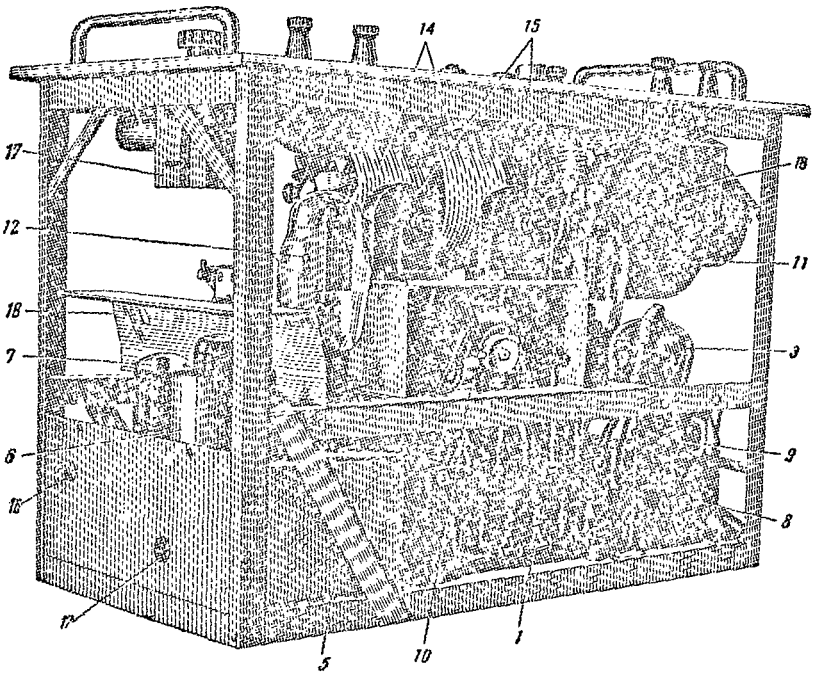


Fig. 201. Location of Parts in UDL-200 Apparatus (Back View With Cabinet Removed).

In the upper part of the chassis, at the left in the back corner, is electric motor 16 for the ventilator. On the back wall (Fig. 201), the power transformer 1 is visible in the center. To the right of it are panel 9 with fuse 8 and sockets for connecting the apparatus to a suitable line voltage. To the left is a shielded compartment 5 which contains the chassis on which the parts of the master generator and intermediate amplifier are mounted. On the left-hand side of this compartment are two openings through which the capacitors for the oscillator circuits in these stages of the circuit can be adjusted. Above this compartment are the vacuum tubes in the master generator 6 and intermediate amplifier 7.

Above them, in the middle of the chassis, is a shielded compartment (in Fig. 201, the front cover of the compartment has been removed), which contains the grid circuit of the output amplifier. Capacitor 10 in this circuit can be adjusted through the opening which is provided for this purpose in the front cover of the cabinet. On both sides of this compartment are tubes 11 and 12 of the output amplifier. Directly above this compartment are the neutrodyne capacitors 15 and behind them is coil 14 of the anode oscillator circuit in the output amplifier. In the

right-hand corner is fan 16 of the ventilator.

On the other side of the control panel are the transformer 17 for the meters (along with a kneotron), the voltage selector switch, a mechanism for transferring the power from the regulator knob to the connecting coil of the therapeutic circuit, and other commutation devices.

Movement is transmitted to the movable connecting coil by /226
means of two pulleys and a wire.

On the back wall of the chassis is an opening closed by a lid, through which the apparatus can be adjusted for the suitable line voltage, the fuse can be changed when necessary, and the electric motor of the ventilator can be switched on and off depending on whether the apparatus is being used for surgery (i.e., without ventilation) or therapy (i.e., with ventilation). To control the ventilator, two sockets marked "therapy" and "surgery" are provided on the plate that holds the fuse. The plug from the ventilator must be plugged into the proper socket on the plate.

The operation of the apparatus when treating the patient is essentially the same as for the UDL-350.

The following are several differences in the manner of operating the UDL-200.

(a) The left-hand meter is a combined voltmeter-milliammeter. When operated as a voltmeter, the instrument requires that the button located below it be pushed. In this position, the line voltage can be checked while adjusting the latter by the voltage compensator. Adjustment is made until the pointer of the voltmeter is on the red line. When the button is released, the meter works as a milliammeter which measures the constant component of the current from the generator tube. This system facilitates monitoring the operating regime of the apparatus.

(b) The circuit contains four adjustable capacitors. The openings which provide access to the adjustable capacitors of the master generator and the intermediate amplifer are located in the shield which surrounds these units, from the rear of the apparatus (see Fig. 201). The adjustment of the capacitor for the grid circuit of the output amplifier is accomplished through an opening in the top of the shield (see Fig. 200). Adjustment of the capacitor in the anode circuit is accomplished by turning the knob located on the right-hand side through opening 18 in the shield (see Fig. 201). Adjustment of all capacitors can be done by means of a special Bakelite tube with notches cut in it. Instructions for adjustment are listed below (see Apparatus UDL-200M).

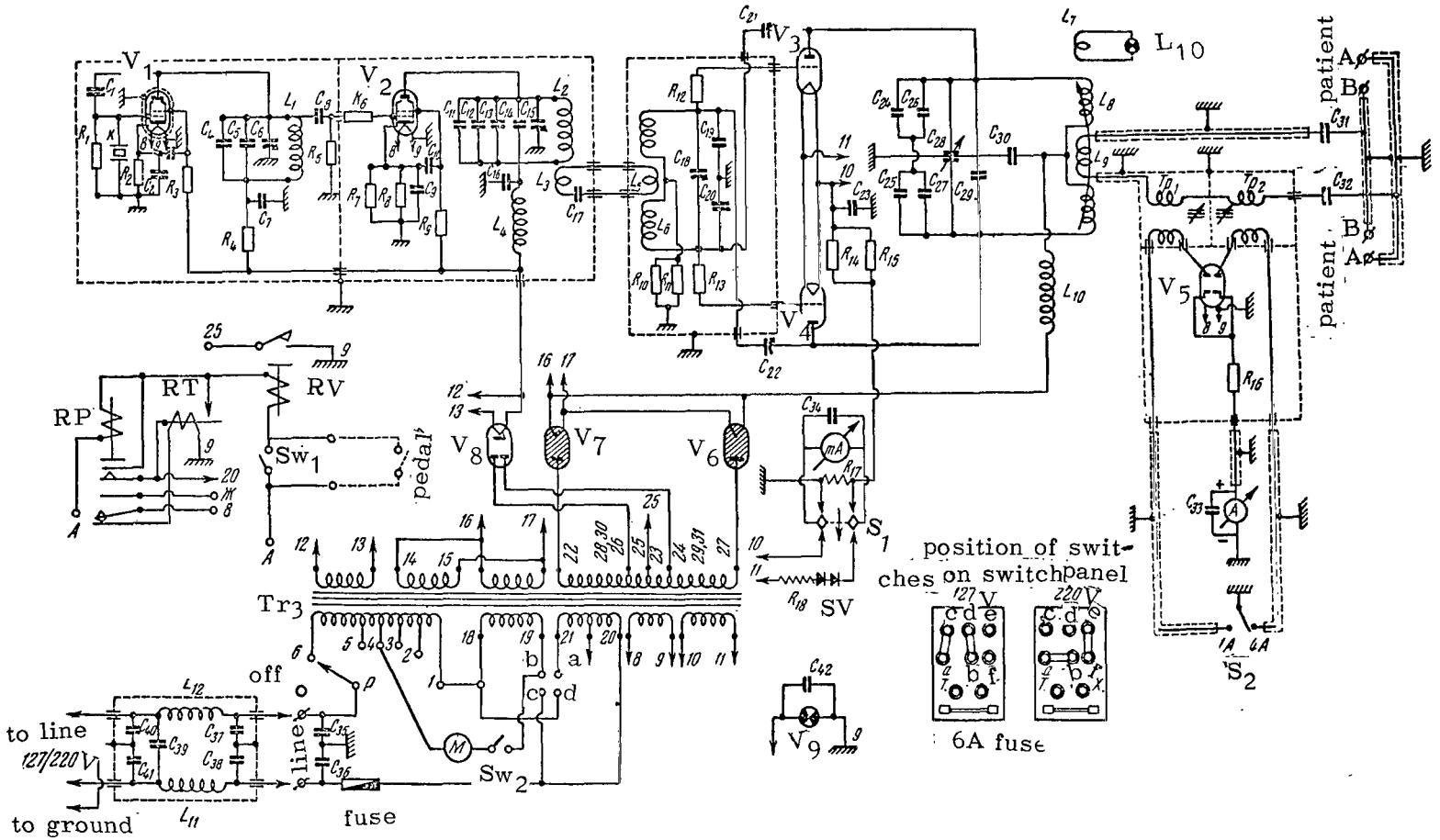


Fig. 202. Schematic Diagram of UDL-200M Apparatus.

Equipment provided with the UDL-200 includes the following:

1. Power cord, 3 m long, with line filter (1).
2. Wires for electrodes, each 2 m long (3).
3. Wires for grounding filter, 3 m long (1).
4. Operating and spare sets of vacuum tubes: 6P6S (2); 6P3S (2); G-811 (2); VG-129 (4); 5Ts4S (2); 6Kh6S (2).
5. Fuse, 6 A (1).
6. Clamps (3).
7. Technical description and certificate.

The apparatus comes with a set of electrodes for therapeutic or surgical use, similar to the materials provided with the UDL-350.

§ 4. UDL-200M APPARATUS

In 1955, the electrical components of the UDL-200 apparatus were modified somewhat, especially in the high-frequency section. For example, in order to reduce the radiation of radio interference, the wires in the therapeutic circuit were shielded, including the wire for the meter circuit. To improve the symmetry of the output stage in order to get rid of even harmonics of the basic frequency, the midpoint of the induction coil was grounded through capacitor C_{30}, etc. The apparatus was then designated as UDL-200M. /228

The schematic diagram of the UDL-200M is shown in Figure 202.

Specifications for Schematic Diagram of UDL-200M

V_1, V_2	Vacuum tube
V_3, V_4	Vacuum tube
V_5	Vacuum tube
V_6, V_7	Gas-filled rectifier
V_8	Kenotron
V_9, V_{10}	Incandescent lamp

Resistors

R_1	VS-I-a, 100 kΩ ± 20%
R_2	VS-2-a, 430Ω ±
R_3	VS-1-a, 160 kΩ ± 20%
R_4	VS-2-a, 10 kΩ ± 20%
R_5	VS-0.5-a, 390 kΩ ± 20%
R_6	VS-0.25-a, 750Ω ± 20%
R_7-R_8	VS-2-a, 510Ω ± 20%
R_9	VS-I-a, 15 kΩ ± 20%
R_{10}-R_{11}	VS-2-a, 2 kΩ ± 20%
R_{12}-R_{15}	VS-2-a, 100Ω ± 20%
R_{16}	VS-I-a, 15 kΩ ± 10%
R_{17}	Shunt
R_{18}	280-300Ω wire-wound

Capacitors

C_1	KDK-I-D 7 nf ± 20%
C_2	KBG-I, 200 V, 0.05 μf ± 20%
C_3	KBG-I, 400 V, 0.05 μf ± 20%
C_4	KTK-4-D, 510 nf ± 5%
C_5	KTK-3-P, 62 nf ± 5%
C_6	KPK-2, 10/100 nf
C_7	KBGI-400 V, 0.05 μf ± 20%
C_8	KSO-2-A, 500 V, 680 nf ± 20%
C_9	KBG-I, 200 V, 0.05 μf ± 20%
C_{10}	KBG-I, 400 V, 0.5 μf ± 20%
C_{11}-C_{12}	KTK-4-M, 200 nf ± 5%
C_{13}-C_{14}	KTK-4-M, 150 nf ± 5%

Inductances

L_1	Circuit coil 10 μh
L_2	Circuit coil 15 μh
L_3	Connecting coil
L_4	Choke 2 mh
L_5	Connecting coil
L_6	Circuit coil 75 μh
L_7	Connecting coil
L_8	Circuit coil 65 μh
L_9	Connecting coil
L_{10}	Choke 2 mh
L_{11}	Choke 60 μh
L_{12}	Choke 60 μh

Other Parts

Kv	Quartz crystal 1625 kHz
T_1	Transformer VCh 3/140 turns
T_2	Transformer VCh 1/120 turns
T_3	Power transformer VA
RT	Thermal relay
RP	Electromagnetic relay
RV	Electromagnetic relay
R	Voltage regulator with switch
M	Electric motor LAG-1
F	Fuse PK 6 A
A-B	Terminals for patient
mA	Milliammeter PM-70
Cv	Selenium rectifier VS18-60
S_1	Pushbutton switch

C_{15}	KPK-2, 10/100 nf
C_{16}	KBG-I, 400 V, 0.05 μf ± 20%
C_{17}	KSO-5-A, 500 V, 10,000 nf ± 20%
C_{18}	KPK-2, 10/100 nf
C_{19}-C_{20}	KTK-4-M, 150 nf ± 5%
C_{21}-C_{22}	Air-gap capacitors 3 + 10 nf
C_{23}	KBG-I, 200 V, 0.05 μf ± 20%
C_{24}-C_{27}	KVKB-3, 47 nf ± 20%
C_{28}	Adjustable capacitor 2 × (25 + 70) nf
C_{29}	Air-gap resistor
C_{30}	KSO-7-A, 2500 V, 510 nf ± 10%
C_{31}-C_{32}	KSO-8-A, 2500 V, 1200 nf ± 5%
C_{33}-C_{34}	KBG-I, 200 V, 0.05 μf ± 20%
C_{35}-C_{36}	KBG-MI, 400 V, 0.1 μf ± 20%
C_{37}-C_{38}	KSO-5-A, 500 V, 6800 nf ± 20%
C_{39}	KBG-I, 400 V, 0.05 μf ± 20%
C_{40}-C_{41}	KBG-MI, 600 V, 0.03 μf ± 20%
C_{42}	KBG-I, 200 V, 0.05 μf ± 20%

S_2	Switch
Sw_1	Switch
Sw_2	Switch

The transformer and other parts as well as the general design /229 of the apparatus remained unchanged.

The factory gives the following instructions for adjusting the UDL-200M and UDL-200 instruments. The circuits in the apparatus may be damaged by vibration or impact during transport, when changing tubes or parts of the circuit, etc. When this happens, the apparatus begins to deliver less power. In addition, a defective apparatus may involve the tubes of the intermediate and output stages being defective, so that such an apparatus must be repaired by using the instructions provided and with careful observation of safety rules for repair.

In addition to reducing the output power, a defect in the apparatus can also be revealed by an increase or decrease in the reading of the milliammeter which is connected to the output stage tube,

relative to the nominal values. If the milliammeter indicates a current exceeding 110 milliamperes when the apparatus is operating without a load, it means that the anode circuit of the output stage is out of order. In order to repair the output stage, it is necessary to insert a screwdriver with an insulated handle through the opening in the right-hand side of the cabinet of the apparatus and increase or decrease the capacitance of the adjustable capacitor C_{28} so that the milliammeter reads the proper value.

If the milliammeter shows a current less than 90 milliamperes when the output stage has been adjusted and the apparatus is running without a load, it means that the intermediate stage or the grid circuit of the output stage is out of order. In order to correct these problems, the apparatus must be removed from the cabinet (by loosening six screws on the control panel) and the anode covers removed from the generator tubes G-811. When these caps have been removed, they should not be placed anywhere in the close vicinity of the chassis or other parts.

In the shields of the exciter and intermediate stages, which are located in the lower right-hand part of the apparatus, as well as the unit for the grid circuit of the output stage, which is located between the G-811 tubes, there are openings for adjusting the capacitors (C_6, C_{15}, and C_{18}).

These units must be adjusted according to the grid current in the tubes of the output stage, so that a DC milliammeter with a 0-50 milliampere range must be connected between resistors R_{10} and R_{11} and the ground.

Adjust is made in the following way. The apparatus must be plugged into the wall and a high voltage turned on as usual. When turning on the high voltage, the pointer of the milliammeter must move somewhat. Then, by turning capacitors C_6, C_{15} and C_{18} one after the other, the maximum grid current for the tubes in the output stage must be set. In a correctly adjusted apparatus, this is 40-50 milliamperes. (Capacitor C_6 must be set so that the exciter operates immediately when the high voltage is turned on.)

A neon lamp (type MN-3 or equivalent) can be used as an indicator, which must be placed between the tubes in the exciter and the intermediate stage, after setting the base of the neon lamp on the shield. In this case, the adjustment is made on the basis of the maximum brightness of the neon lamp.

As soon as the grid current of the tube in the output stage has been adjusted (40 milliamperes or more), the apparatus must be disconnected, the covers replaced on the anodes of the tubes, and the apparatus replaced in the cabinet. It is also necessary to adjust /230 the output stage. We must keep in mind that the adjustment of the output stage depends on whether the apparatus is located inside the cabinet or outside of it. Therefore, if we wish to adjust the out-

put stage when the apparatus is outside the cabinet, then it is necessary to adjust the output stage after the apparatus is replaced in the cabinet.

If it is not possible to obtain a grid current for the tubes of the output stage which is about 40 milliamperes, it means that the circuit is out of order. The first thing to do then is to replace the tubes in all of the stages one after the other, and if this does not help, then other sources of trouble must be found. Changing the tubes in the apparatus does not require other adjustments to be made.

§ 5. APPARATUS FOR SURGICAL DIATHERMY EN-57

The EN-57 apparatus (whose factory designation is "apparatus for coagulation and cutting by high-frequency current", or "electric knife") was devised in 1958 by the VNIIEKhAiI and is produced by the Union Factory of the EMA as well as by the Volgograd Factory for Medical Supplies.

The basic data of the apparatus are as follows: operating frequency, 1900 ± 100 kHz; output power = 200 watts.

The power consumption is 1700 volt-amperes.

The overall dimensions are 530 × 420 × 160 mm. It weighs approximately 80 kg.

The apparatus is shielded from radio interference and can be used without a shield.

Since the apparatus is powered by AC, the high-frequency current of the output of the apparatus has an irregular, modulated character. Such a current shape is favorable for the cutting of soft tissues (muscle, fat, parenchyma).

The apparatus has separate output terminals for working with monactive or biactive electrodes; these terminals are connected to the circuit by means of a special switch and therefore make it possible to switch from one method to the other and back again during an operation.

The schematic diagram of the apparatus is shown in Figure 203. It consists of a high-frequency generator which operates with self-excitation using two GK-71 tubes connected in parallel (marked V_1 and V_2 in the circuit) with negative feedback and parallel power (see the diagram in Fig. 171, b). The oscillator circuit consists of an induction coil L_1 and two groups of capacitors C_{14} and C_{15}-C_{18} connected in series. Capacitors C_{15}-C_{18} are connected in parallel. The midpoint between the groups of capacitors is grounded. Capacitors C_{15}-C_{18} produce the feedback on the control grids.

Coil L_1 is inductively linked to circuit coil L_1 in the therapeutic circuit. The latter contains the output inductive rheostat (potentiometer) B and the parts of the two resonance circuits which are intended to supply the oscillations of the basic frequency to the output and to suppress as much as possible the oscillations of the second harmonic to prevent their being radiated into the patient's circuit.

Induction coils L_2 and L_3 are used for compensating the capacitive conductance of the wires in the therapeutic circuit. Connecting them gets rid of the asymmetry of the field formed by the wires running to the patient's electrodes, thus reducing the radiation of noise at the basic frequency.

A circuit consisting of coils L_4 and L_5 and capacitors C_{19} and C_{20} can be adjusted to the basic frequency by using a system of following resonance. The circuit consisting of coils L_6 and L_7 and capacitors C_{28} and C_{30} produces the basic frequency, since one of its branches, containing inductance L_7 and capacitor C_{30}, is in resonance with the second harmonic of the frequency. This means that the second harmonic is formed between the circuit consisting of L_7- /231
C_{30} and its amplitude at the output of the therapeutic circuit is considerably reduced.

Fuse F_3, shunted by pilot light Lo_2, is connected in series with the inductive potentiometer B in the circuit. The pilot light, whose lens is located on the control panel, lights up when the fuse blows out.

A current-limiting resistor R_7 is connected in series with the lamp. Capacitors C_{22} and C_{23} are connected to the line running from potentiometer B to the output terminals; they prevent the possibility of low-frequency pulses arising in the patient's circuit due to the rectifying effect of a spark when cutting. The wires are connected to the output terminals by switch Sw_2.

The negative bias on the tube grids is produced by the grid current flowing through resistor R_6. Choke Ch_3 and capacitor C_{11} block the resistance from the high-frequency component of the grid current.

The power for the generator comes from the step-up winding of the power transformer, whose end terminal is grounded. The power circuit for the anodes of the tubes contains blocking choke Ch_4, shunted by capacitor C_{12}. The anode circuit of each tube contains an antiparasitic resistance (R_4 and R_5) which serves to prevent the appearance of UHF oscillations in the circuit which consists of the lead inductances of the tubes and the connecting wires as well as the capacitances between the tube electrodes, as well as capacitors C_{13} and C_{14}. The oscillator circuit contains a separating capacitor C_{13}.

The supply voltage from the middle leads of the transformer also run to the shielding and screen grids of the tubes. A voltage of 2000 volts is applied to the anodes, 500 V to the screen grids, and 50 volts to the shielding grids. The screen grids are connected with the cathodes at high frequency by means of capacitors C_4, C_4^1, and C_7, C_7^1. The filaments of the tubes are powered from a separate winding on the transformer through blocking chokes Ch_1 and Ch_2. The high-frequency potentials on the filaments of the tubes are balanced by means of capacitors C_5 and C_6.

The tube cathodes are grounded for high frequency by means of capacitor C_{10} and are themselves connected with the midpoint of the capacitance branch of the oscillator circuit. The shield grids are connected for high frequency with the tube cathodes through capacitor C_{35}.

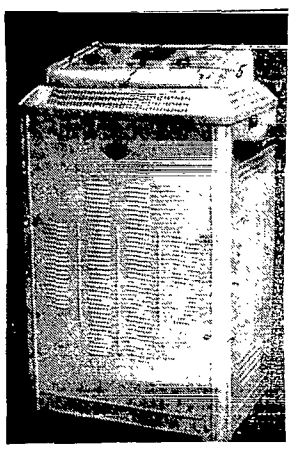


Fig. 204. General View of EN-57 Apparatus for Surgical Diathermy.

Chokes Ch_1, Ch_2, Ch_5 and Ch_6 along with capacitor C_8, C_9, C_{12}, C_{32}, C_{33} and C_{34}, which ground the corresponding leads, form filters which prevent a drop in the high-frequency oscillations in the transformer windings, and also get rid of radiation of radio interference by the connecting wires which /232 are located outside of the shielded high-frequency block. (The screening of the generator unit is shown on the diagram as a diashed line.)

The cathode circuit of the generator tubes, which connect with the filament power supply, contains pilot light LS_1, shunted by resistor R_3 and the contact of relay R, which close when the pedal is activated and connect the power supply of the generator tubes to ground. The contacts of the relay are shunted by a circuit consisting of resistor R_{10} and capacitor C_{31}, which extinguish sparks when the contact opens thus preventing radiation of radio interference when they operate. The coil of relay R is powered by smoothed direct current. The rectifier (selenium rectifier VS with capacitor C_3 for smoothing the pulses) is connected to a separate winding of the transformer, in series with the contacts P of the pedal.

The primary of the transformer is divided into sections to accommodate 127 or 220 volts, and is connected into the line in series with the windings of a voltage compensator. The power voltage for the circuit is monitored by means of voltmeter V, which is connected to the supply winding for the tube filaments. The voltmeter is

shunted by capacitor C_{24}.

The primary circuit contains fuses F_1 or F_2, contacts B_1 and B_2 of the interlocks for the removable sides of the cabinet, and the noise-suppresssing capacitors C_1 and C_2.

Specifications for Schematic Diagram of EN-57 Apparatus

L_1-L_2 Vacuum tube GK-71

Resistors

R_1	VS-2, 360Ω ± 20%
R_3	Wire-wound 6.5Ω
R_4-R_5	VS-5, 51Ω ± 5%
R_6	PE-20, 3.5 kΩ ± 5%
R_7	VS-2, 2 kΩ ± 50
R_{10}	VS-1, 580Ω ± 20%

Inductances

L_1	Circuit Coil 19 μh
L_0	Line coil 8.5 μh
L_2-L_3	Filter Coil 100 μh
L_4-L_5	Filter Coil 19 μh
L_6	Filter Coil 6 μh
L_7	Filter Coil 14 μh
L_8-L_9	Coil 12.5 μh
Ch_1-Ch_2	Choke 40 μh
Ch_5-Ch_6	Choke 2 μh
B	Potentiometers 2 x 52 μh

Other Parts

LS_1-LS_2	Miniature bulb MN-14, E-10 6.3 V, 0.2 A
Tr	Transformer 1700 VA
V	Voltmeter 3421 0-50 V
VS	Selenium rectifier ABC-18-71
F_1-F_2	Fuses for 20 A, 10 A
F_3	Fuse

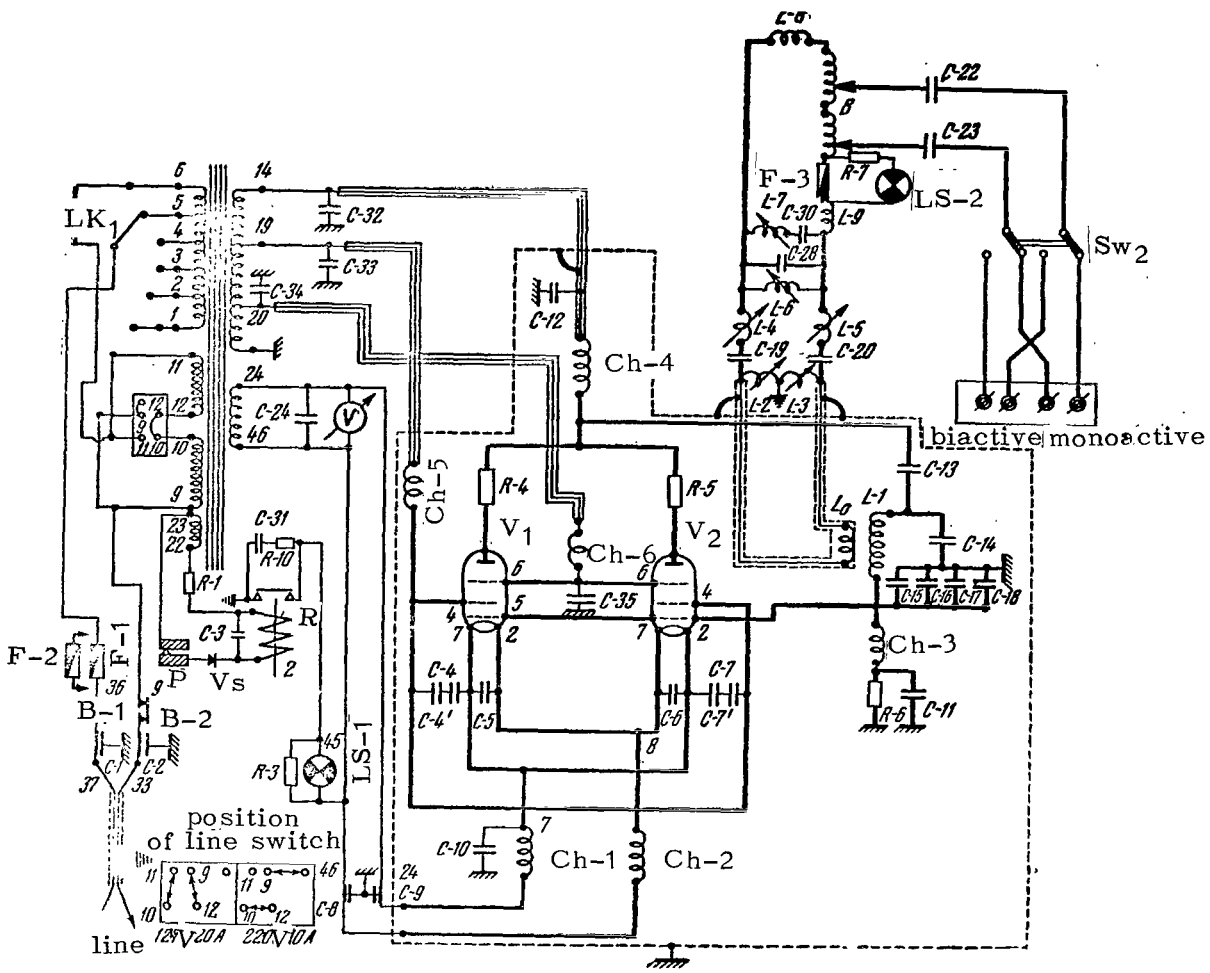
Capacitors

C_1-C_2	KBP-S, 500 V, 20 A, 0.1 μf ± 10%
C_3	KE-2, 300 V, 30 μf
C_4-C_7	KSO-10, 2000 V, 10,000 nf ± 10%
C_8-C_9	KPB-S, 500 V, 20 A, 0.1 f ± 10%
C_{10}-C_{11}	KSO-10, 2000 V, 10,000 nf ± 10%
C_{12},C_{14}	KBKT-6, 470 nf ± 10%
C_{13}	KBKT-1, 2200 nf ± ω^{0}±
C_{15}-C_{18}	KBKT-5, 560 nf ± 10%
C_{19}-C_{20}	KBKT-7, 330 nf ± 10%
C_{22}-C_{23}	KBKT-5, 560 nf ± 100
C_{24}	KBG-I, 600 V, 0.01 μf ± 10%
C_{28}	KBKT-1, 1500 nf ± 10%
C_{30}	KBKT-9, 120 nf ± 10%
C_{31}	KBG-MP-1, 1000 V, 0.1 μf ± 20%
C_{32}	KVKG-6 470 nf ± 10%
C_{33}	KVKG-5 560 nf ± 20%
C_{34}-C_{35}	KSO-10 2000 V, 10,000nf ± 20%

PK_2	Switch
R	Relay RKS-3
PK_1	Switch
P	Pedal
B_1-B_2	Interlock

A general view of the apparatus is shown in Figure 204, while the arrangement of the parts in the apparatus is shown in Figure 205. The apparatus is mounted in a metal cabinet with a sloping control panel. The following parts are mounted on the panel (Fig. 204): at the bottom left is knob 1 for the voltage compensator, which is used to adjust the apparatus to the line voltage and then

to regulate the normal voltage for its supply in the generator. At the top left is lens 2 of lamp (LS_1), which signals that the power is connected to the anode circuit of the generator when the pedal /233 is depressed.



1. Dashed line = PVLE wire
2. Three dashed lines=PVL-3 wire
3. Heavy line=MMF 2.02 wire, silver
4. Thin line = MPGP(G) wire, 2.5 mm^2

Fig. 203. Schematic Diagram of EN-57 Apparatus for Surgical Diathermy.

At the top center is voltmeter 3, with a red line on the scale which corresponds to the normal supply voltage; at the bottom center is a pushbuttom switch 4 for the output terminals for two-electrode and one-electrode operation; at the bottom right is knob 5 for the variable potentiometer for high-frequency current, and below is lens 6 of the lamp (LS_2) which signals that the fuse in the high-frequency circuit has burned out. On the back of the control panel there are four output terminals.

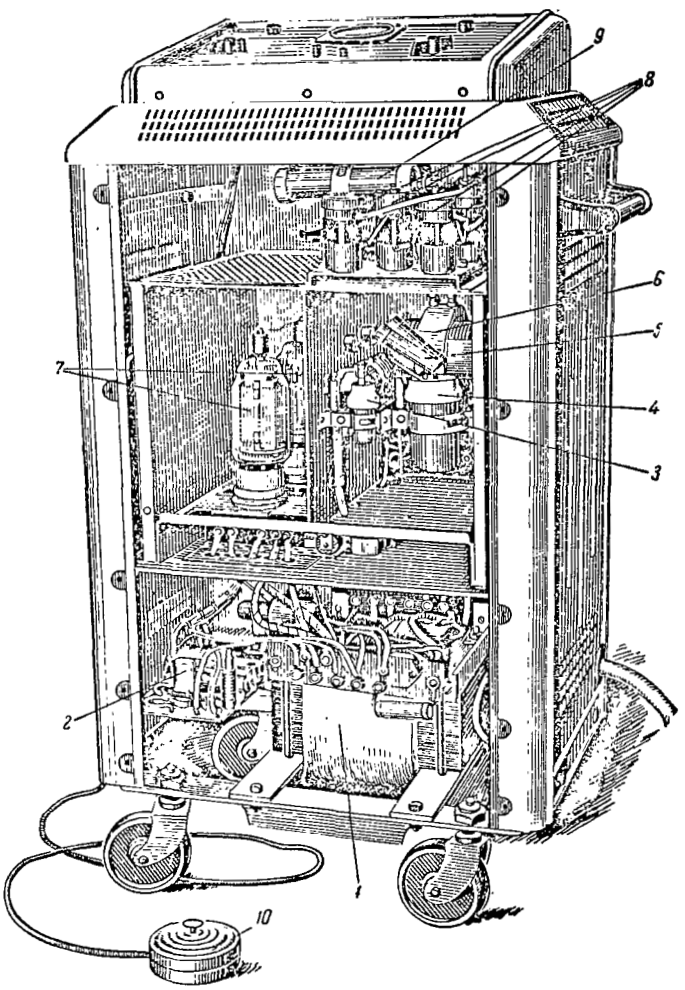


Fig. 205. Location of Parts in the EN-57 Apparatus.

On the back of the cabinet is a window behind which is a cover with screws for changing the primary winding of the transformer to match either 127 or 220 volt current and for replacement of the line fuse (20 amperes for 127 volts, 10 amperes for 220 volts). On the

side of the cabinet there is an opening with a socket for plugging in the cord from the pedal.

The parts of the machine (Fig. 205) are located inside the /231 cabinet on three shelves. At the bottom is transformer 1 and relay block 2, along with the rectifier. On the left-hand side of the second shelf are the generator tubes 7, and on the right side are the high frequency circuits which are covered by a shielded cover with removable sides (Fig. 25 shows the front side of this shield removed.) The compartment containing the high frequency circuits has the following designations: (3-4) pot capacitors; (5) tubular capacitors; (6) inductance coil. Above the shielded compartment is high frequency filter 8 for the therapeutic circuit. A dual output regulating potentiometer 9, a fuse and capacitors in the line of the output terminals are mounted on the back of the control panel. On the back of the apparatus is a window protected by a lid; this window provides access to the panel on which the switches for changing the transformer windings to match the line voltage are mounted; it is also used for replacing the fuses. On the side of the cabinet there is an opening for connecting the pedal.

The apparatus is connected to the line by means of a two-wire line cord and must be grounded; the line cord is fitted with a third lead as a grounding clip.

The apparatus is used as follows. After checking that knob 1 of the voltage compensator is in the "off" position and knob 5 of the current regulator is in the "0" position, the plug can be inserted into the wall socket. Knob 1 is set to the first working position (admitting line voltage to the transformer) and is turned until the voltmeter needle reaches the middle of the red area on the scale. During the procedure itself, the current is regulated by turning knob 5 clockwise and turning on the voltage each time by means of the pedal.

The apparatus is supplied with: spare GK-71 tubes (2); fuses for 10 and 20 A; wire for the electrode (2 m long) (3); clamps (3); a pedal; set of electrodes for coagulation and cutting (see Fig. 196,b); the description and instructions.

PART 4

APPARATUS FOR D'ARSONVALIZATION

At the same time that the manufacture of spark apparatus was discontinued, the production of apparatus for general and local d'arsonvalization was discontinued, since the basis of the latter instruments was a spark generator of damping oscillations. It became necessary to devise similar vacuum tube generators.

In making the transition from the spark circuit to the vacuum tube circuit, it was necessary to determine the essential characteristics of the electrical process used for treating the organism in this method. In this regard, the most characteristic feature of d'arsonvalization (as we know) is the highly transient nature of the electromagnetic oscillations at considerable amplitudes of the initial oscillations in each series. This corresponds to a considerable extent to the pulsed regime of nondamped oscillations. In both cases, the oscillations are characterized by a high peak voltage and a low average power. This means, for example, that in local d'arsonvalization there is practically no thermal effect, while a rather high voltage makes it possible to use a capacitor electrode which acts as a "cold" (painless) spark.

In accordance with this, the basic medical and technical requirements set for the apparatus to be used for local d'arsonvalization with a vacuum-tube circuit was formulated as follows: the apparatus must produce electrical oscillations in a pulsed regime using the frequencies set aside for this purpose, with a duration of the modulator pulses on the order of 50-100 microseconds, a repetition frequency of 50 or 100 Hz, and a peak voltage corresponding to a spark "to ground" 20-35 mm long (as in the spark apparatus). /235

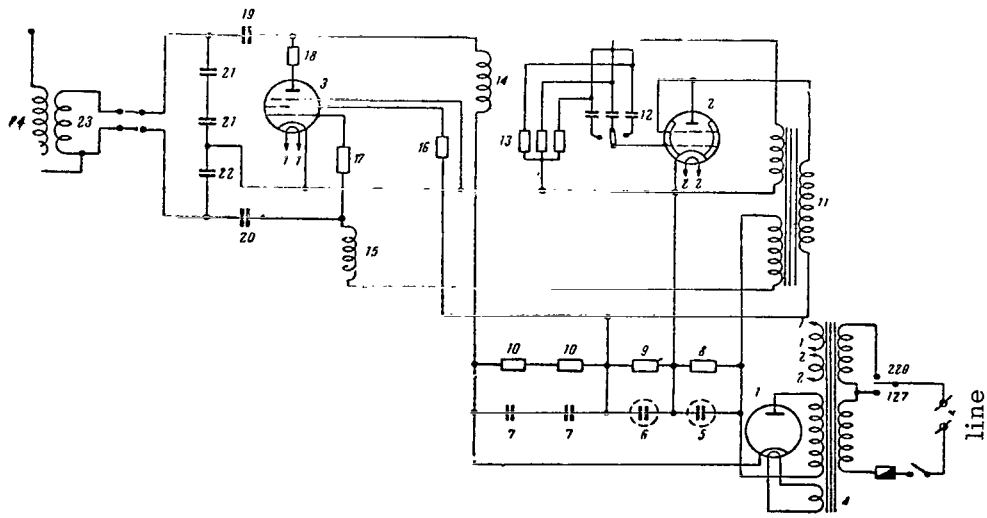


Fig. 206. Schematic Diagram of Vacuum Tube Apparatus for Local D'arsonvalization.

On the basis of these data, the State Institute of Physical Therapy in 1953 devised a vacuum-tube apparatus for d'arsonvalization and built a sample model. The schematic diagram of this apparatus is shown in Figure 206. The basis of the circuit is a generator of electrical oscillations at a frequency of 150 kHz with self-excitation, with parallel power and modulation on the control grid produced by a blocking generator which produces produces modulating pulses of the type described above. The generator uses a GU-50 tube (3). The anode circuit of the generator contains an oscillator circuit consisting of coil 23 and capacitors 21 and 22. Capacitor 20 produces the feedback for the oscillator circuit with a controlled grid. The control grid of the tube receives an independent bias (with section 8 of voltage divider 8-9-10). The bias circuit for the grids is blocked by high-frequency choke 15. The screen grid of the generator tube 3 is powered from the voltage divider (resistor 9) through resistor 16. The anode circuit of tube 3 is powered from a voltage divider (resistors 9 and 10) through a high-frequency choke 14. Capacitor 19 acts as a divider. The anode circuit contains an antiparasitic resistor 18.

The blocking generator operates with the 6T3 tube (2). The anode circuit of the tube is powered from a voltage divider through the winding of transformer 11. The screen grid of the tube is connected to the anode. The control grid is connected to the third winding of the interelectrode transformer 11, in series with the adjustable capacitor 12. Leak resistors 13 are connected in parallel with the grid and capacitor 12. The ratio of capacitor 12 and resistor 13 at each stage is set so that a constant frequency of the blocking pulses is produced (100 impulses per sec). Under these conditions, changing capacitor 12 produces regulation of the pulse duration. /236

This circuit makes it easy to adjust the frequency of the modulating pulses by changing the ratio between capacitor 12 and resistor 13 to different settings, thus determining the time constant of the corresponding circuit.

The generator is powered by direct current. Alternating current from the step-up winding of transformer 4 is rectified by kenotron 1 and smoothed by means of a group of capacitors 5, 6, 7 connected in series.

The operating principle of the apparatus is as follows: tube 3, which generates oscillations at the basic frequency, is closed by a high negative bias supplied to the control grid. The grid circuit contains the winding of the blocking generator transformer in series. When the blocking generator operates, the grid of the basic frequency generator receives a positive pulse, which unlocks the tube; the tube then generates oscillations at the basic frequency. These oscillations are considerably increased in voltage by means of a resonator and then transmitted to the electrode. The resonator winding 24 of the autotransformer is connected to coil 23 of the oscillator circuit.

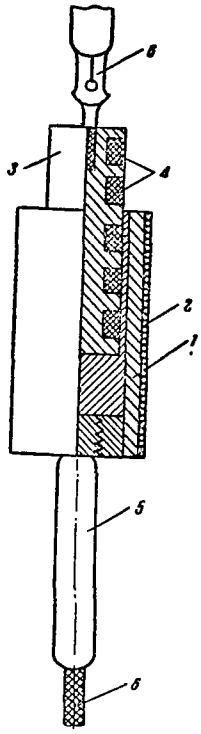


Fig. 207. Diagram of Resonator Design in the Apparatus for Local D'arsonvalization, with a Vacuum-Tube Circuit.

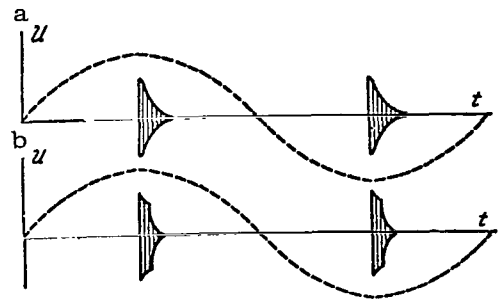


Fig. 208. Graph Showing Oscillations in the Apparatus Used for Local D'arsonvalization (Sketched from the Screen of a Cathode Ray Oscilloscope). a. Spark Apparatus; b. Vacuum-Tube Apparatus.

The resonator (Fig. 207) consists of a hollow ebonite cylinder 1, on which the windings 2 of the primary winding are wrapped. Within this cylinder is a second, solid ebonite cylinder 3, in whose grooves there is a second winding, made up in section of 300 turns per section (4 in the diagram). Both cylinders are covered with paraffin. The resonator is covered with artificial leather. At one end of the ebonite casing is a handle 5 for the electrode holder, while at the other end is a holder 6 for the vacuum electrode.

Figure 208a shows a schematic diagram of the oscillations of a spark apparatus for local d'arsonvalization. Depending on the regulation of the discharge (the distance between poles), it is possible to obtain during one-half period of supply voltage, one or several series of brief oscillations. In Figure 208b, we can see similar curves for an apparatus with a vacuum tube-circuit (in the graphs, the time scale is given by the line voltage shown as a dotted line). As we can see from the diagram, the vacuum-tube circuit gives brief pulses of oscillations at the basic frequency, whose shape is close to the sharply cut-off spark oscillations. The length of the pulses is equivalent to the doubled or combined series of oscillations in the spark apparatus. /237

When using the apparatus in the clinic, an effect is obtained which does not differ in any way from the effect produced by the spark apparatus. However, tests have also shown that the apparatus (especially the electrode which forms an open oscillator circuit

with the patient) produces radio interference which exceeds the level which is permitted; therefore, it must be used in a shielded chamber.

In addition, the medical and technical requirements were formulated for a vacuum tube apparatus for general d'arsonvalization.

At the present time, the problem of devising vacuum tube apparatus for general and local d'arsonvalization is being worked on by VNIIMIO. The principal difficulty in this problem is shielding the apparatus against emission of radio interference. The problem of producing these devices has not yet been solved.

PART 5

APPARATUS FOR INDUCTOTHERMY

§ 1. APPARATUS FOR INDUCTOTHERMY, DKV-1

This apparatus was devised by VNIIMIO. It has been produced by the Union Factory of the EMA since 1951. In 1952, the electrical circuit of the apparatus was changed somewhat by the factory and it is in this form that the apparatus has been produced since 1956.

The basic data are as follows: the apparatus is a three-stage generator of electric oscillations of high frequency, with quartz stabilization. The generator frequency is 13.56 $\pm$ 0.007 mHz. The nominal power of the generator is 350 $\pm$ 50 watts (with an equivalent load resistance of 4.3 ohms).

The current which the apparatus draws from the line is 10 amperes at 127 volts and 5.5 amperes at 220 volts (a power of approximately 1200 volt-amperes). The apparatus is provided with a line filter for suppressing radio interferences.

The overall dimensions of the apparatus are 400 x 615 x 918 (without the electrode holder). It weights approximately 85 kg.

The schematic diagram of the apparatus is shown in Figure 209. It is largely similar to the UDL-350 apparatus and also has five sections: (1) master generator, (2) intermediate amplifier, (3) output amplifier, (4) therapeutic circuit, (5) power supply.

The master generator uses a 6F6 tube (8) and is stabilized by a quartz crystal. The basic oscillator circuit is produced in the cathode circuit and consists of inductance coil 7 and two capacitors connected in parallel: one of fixed value (4) and one adjustable (3). The oscillator circuit operates at a frequency of 6.78 MHz, which corresponds to the frequency of the natural oscillations of the quartz. The quartz 2 is connected between the control grid and the cathode oscillator circuit. The bias on the control grid is produced by the voltage drop across resistor 6, which is con- /23

nected to the cathode circuit and shunted by capacitor 5, and leak resistor 1, which is connected between the control grid and the cathode.

The anode load of the tube is the oscillator circuit consisting of coil 11 and adjustable capacitor 12. The oscillator circuit produces basic oscillations at the frequency of the second harmonic, i.e., at a working frequency of 13.56 MHz for the apparatus, and is connected for high voltage to the cathode circuit of capacitor 13.

The anode circuit of the master generator is powered from the kenotron rectifier through resistor 106. The tube anode receives a voltage of 270 volts. The power for the screen grid of the tube is produced through resistor 10. The grid is grounded for high frequency through capacitor 9. The voltage which is produced on the screen grid is 180 volts.

The intermediate amplifier uses the G-807 tube (19). The voltage on the control grid of tube 19 comes from the anode circuit of the master generator through separating capacitor 14. The bias on the grid is produced by the voltage drop across resistors 16 in the grid circuit and 18 in the cathode circuit. The latter is shunted by capacitor 17.

The screen grid of the tube is powered from the kenotron rectifier through resistor 30 and is connected for high frequency with the cathode through capacitor 29. The voltage applied to the screen grid is 215 volts.

The anode circuit of the amplifier consists of coil 24 and adjustable capacitor 20, and is set to a basic generator frequency of 13.56 MHz. The anode circuit of the tube contains an antiparasitic resistor 21. The oscillator circuit is connected with the cathode for high frequency by capacitor 23.

The anode circuit of tube 19 is powered by the gas-filled rectifier through quenching resistor 27 and high-frequency choke 26, blocked by capacitor 28. The voltage supplied to the tube anode is 620 volts.

The output amplifier is in the form of a two-stage circuit using GK-71 tubes (46 and 47). The connection of the output amplifier with the intermediate amplifier is accomplished by means of connecting coils 25 and 32 through induction; the latter are linked with the screen grid as well as with the coils of the anode circuit in the intermediate and grid circuits of the output amplifier.

The grid oscillator circuit of the output amplifier consists of coil 33 and double capacitor 34 (adjustable) with the center-tap grounded. (Capacitor 34 is adjusted to regulate the apparatus.)

The bias on the control grids is produced by the voltage drop on resistor 37, connected in the grid circuit, and shunted by capacitor 36, and by resistors 40 and 43 which are connected in the cathode circuit. The grid passes through high-frequency choke 35. The grid oscillator circuit operates at the basic frequency of the generator which is 13.56 MHz.

The voltage on the screen grids of the tubes passes from the kenotron rectifier through the stepped potentiometer 83. Changes in the voltage on the screen grids are regulated by the power of the output amplifier and so is the power in the therapeutic circuit.

The screen grids are grounded at high frequency by capacitors 58 and 60.

The voltage on the shield grids (20-30 volts) comes from the kenotron rectifier through the voltage divider which consists of resistors 48 and 49; at high frequency, the grids are grounded through capacitors 56 and 61.

The anode oscillator circuit of the output amplifier consists of coils 74-76, the interelectrode capacitances of the generator tubes, and the variable capacitors 77 and 78 (the midpoint between them is grounded). The power for the anode circuit comes through /23
the center tap of the coil from the gas-filled rectifier through limiting resistor 72, blocked by capacitor 59. A voltage of 1500 volts is applied to the anodes of the generator tubes.

The circuit for the cathodes of the GK-71 tubes contains milliammeter 39, shunted by capacitor 38. The milliammeter is used to measure the constant component of the cathode current of the tubes in the output amplifier. This current, according to the certificate provided with the apparatus, must be 260 milliamperes without load and 440-460 milliamperes with full load.

The heater circuit of the generator tubes is blocked for high frequency by capacitors 52-55. In the circuit which powers the tube filaments, there are protective chokes 50 and 51.

Between the anode of each tube and the grid of the next tube there is a neutrodyne capacitor 44 or 45.

The connection of the anode circuit with the therapeutic circuit is by induction and is constant, being accomplished by connector 75. The therapeutic circuit contains a double capacitor of variable value, 79 and 80. The coil in the anode circuit is connected to a terminal which is also linked to pilot light 87, which indicates that there is oscillation in the circuit.

In this apparatus, the following parts are shielded (shielding is represented by a dashed line in Fig. 209): (a) the master generator without the anode circuit; (b) the anode circuit of the

master generator and the intermediate amplifier without the anode circuit; (c) the anode circuit of the intermediate amplifier; (d) the line circuit of the output amplifier; (e) the output amplifier together with therapeutic circuit are shielded by the chassis of the apparatus.

The power supply has some auxiliary circuits. The power for the generator comes from the power transformer 88 and two rectifiers which operate in a full-cycle circuit: the gas-filled rectifier is 1600 volts while that from the kenotron rectifier is 400 volts.

The rectifier which uses the VG-179 gas-filled rectifiers does not have a ripple filter and powers the anode circuits of the tubes in the intermediate and output amplifiers; the kenotron rectifier has a ripple filter for smoothing the pulsation 81 and powers the master generator, the screen grid of the tube in the intermediate amplifier, and the antidynatron and screen grids of the tubes in the output amplifier.

The power transformer has the following: (a) two primary windings for connecting the apparatus to voltages of 127 or 220 volts; (b) a voltage compensator winding 93, which permits normal operation of the apparatus if the line voltage changes within ± 25%; (c) a filament winding which provides a voltage of 20 volts (for powering the GK-71 tube), 6.3 volts (for the 6F6 and G-807 tubes), 5 volts (for the 5Cs4S kneotron) and 2.5 volts (for the VG-9 gas-filled rectifiers); (d) a step-up winding whose outer leads are used to power the gas-filled rectifier and whose inner leads are used for the kenotron rectifier.

The filament winding for 6.3 volts is also connected to the heating element for the time-delay relay (required for allowing the gas-filled rectifiers to warm up properly) and voltmeter 91, which is connected through selenium rectifier 90 and shunted by capacitor 98.

The primary circuit of the power transformer contains contacts 92 of the interlock for the removable sides of the cabinet, fuse 109, and voltage compensator 93, which turns off the apparatus when the knob is turned all the way.

To suppress radio interference, the supply circuit of the apparatus is fitted with a filter consisting of two high-frequency chokes 97 and 99 and capacitors 15, 57, 96, 100, 101, 102, 105 and 107, which are located in a separate compartment. The line cord which runs from the apparatus to the filter is shielded. The filter is fitted with a terminal for grounding. Two short wires run from the filter and are provided with terminals for connecting to the socket on the power panel. /240

The apparatus operates as follows. When the instrument is

plugged into the wall, the voltage from the latter passes through the compensator to the primary winding of the power transformer 88. The filament winding is connected to all vacuum tubes as well as the generator and power supply, in addition to the gas-filled rectifiers and kenotrons. The high voltage is not yet admitted to the circuit.

The time required for the gas-filled rectifiers to warm up (3-5 min) is determined by means of thermal-delay relay 108, which operates to connect the intermediate and actuating electromagnetic relay. The latter connects the high-voltage circuit to power the generator. The contacts of the relay are connected with the circuit at the center tap of the step-up winding of the transformer, which acts as the negative pole of the rectifier.

To close the contacts of the electromagnetic relay, it is necessary on the one hand that the intermediate relay operate and on the other hand that switch 94 be turned on from the control panel. The operation of the relay block is the same as in the case of the UDL-350 apparatus.

When the power is switched on, the master generator is activated and oscillations at the frequency of the quartz crystal (i.e., 6.78 MHz) are produced in its basic oscillator circuit which is connected to the cathode. The oscillations are also produced in the anode circuit of the generator. The latter is set for a double frequency (3.56 MHz), containing the second harmonic of the quartz oscillations that correspond to this frequency. A portion of the oscillation energy from the anode circuit passes through separating capacitor 14 to the control grid of the tube in the intermediate amplifier. At the same time, the anode circuit of the intermediate amplifier is subjected to oscillations at a frequency of 13.56 MHz, which are considerably amplified in power relative to the oscillations in the master generator.

A portion of the energy from the anode circuit of the intermediate amplifier passes through the connecting coils 25 and 32 to the circuit coil for the control grid to the output amplifier, so that in the anode circuit of the latter there are oscillations at a frequency of 13.56 MHz (for which it is designed) but the power is much greater.

To do away with harmful effects of interelectrode capacitance in the tubes (anode-grid), the output amplifier is provided with neutralization (capacitors 44 and 45). The value of capacitors 44 and 45 is set at the factory in the process of calibrating the apparatus.

The use of electric oscillations at frequencies considerably in excess of the frequencies used in diathermy, as is the case in inductothermy, makes it necessary to set up the therapeutic circuit for each procedure. This is because at the frequencies used here,

the differences in the capacitive components of the load resistors in different procedures will have an effect on the state of the therapeutic circuit. This means that the therapeutic circuit must be fitted with an adjustable capacitor, which can be used to set the circuit in resonance for each procedure.

A milliammeter 39 is used as an indicator for this process, and it is connected in the supply circuit for the output amplifier.

Specifications for Schematic Diagram for DKV-1 Apparatus /241

1	Resistor VS-0.5; 120 kohm ± 10%
2	Quartz Crystal 6.78 MHz
3	Capacitor KPK-3; 6-60 micromicrofarad
4	Capacitor KTK-2: 60 micromicrofarad ± 10
5	Capacitor KBG-M1; 200 V, 0.02-0.1 microfarad
6	Resistor VS-2; 440 ohm ± 10%
7	Coil
8	Vacuum tube 6F6
9	Capacitor KBG-M1; 600 V, 0.02-0.1 microfarad
10	Resistor VS-2; 33 kohm ± 10%
11	Coil
12	Capacitor KPK-3; 6-60 micromicrofarad
13	Capacitor KBG-M1; 600 V, 0.02-0.1 microfarad
14	Capacitor KTK-3; 150 micromicrofarad ± 10%
15	Capacitor KSO-5; 500 V, 5000 micromicrofarad ± 10%
16	Resistor VS-2; 24 kohm ± 10%
17	Capacitor KBG-M1; 200 V, 0.02-0.1 microfarad
18	Resistor PE. Type 1, 500 ohm ± 10%
19	Vacuum Tube G-807
20	Variable capacitor
21	Resistor VS-5; 500 ohm ± 10%
23	Capacitor KSO-10; 2000 V, 0.01 microfarad ± 20%
24	Coil
25	Circuit coil
26	Choke (see below)
27	Resistor PE. Type IV, 4 kohm ± 10% (3 in series)
28	Capacitor KSO-10, 2000 V, 10,000 micromicrofard ± 20%
29	Capacitor KBG-M1; 600 V, 0.02-0.1 microfarad
30	Resistor PE. Type 1, 5 kohm ± 10%
31	Pilot light MN-15; 6.3 V, 0.28 A
32	Circuit coil
33	Coil
34	Variable capacitor
35	Choke (see below)
36,38	Capacitor KSO-5; 500 V, 3300 micromicrofarad ± 20%
37	Resistor PE. Type II, 2 kohm ± 10%
39	Milliammeter PM-70
40-43	Resistor PE. Type II, 100 ohm ± 10%
44-45	Neutrodyne Capacitor
46-47	Vacuum tube GK-71

48	Resistor VS-2; 51 kohm ± 10%;(2 in parallel)
49	Resistor VS-2; 39 kohm ± 10%
50-51	Choke (see below)
52-55	Capacitor KSO-5; 250 V, 5100-10,000 micromicrofarad
56,58	Capacitor KSO-12; 1000 V, 6800-10,000 micromicrofarad
57	Capacitor KSO-5; 500 V, 5000 micromicrofarad ± 10%
59	Capacitor KSO-13; 5000 V, 1800 micromicrofarad ± 20%
60-61	Capacitor KSO-12; 1000 V, 6800-10,000 micromicrofarad
62-66	Resistor PE. Type II, 2 kohm ± 10%
67-71	Resistor PE. Type II, 4 kohm ± 10%
72	Resistor PE. Type III, 100 ohm ± 10%
74-76	Inductance coil
77-80	Air-gap capacitor, variable
81	Capacitor KBG-M1; 600 V, 0.02-0.1 microfarad
83	Switch
84-85	Vacuum Tube VG-129
86	Vacuum Tube 5Ts4S
88	Transformer
89	Resistor PE, Type III, 1000 ohm ± 10%
90	Selenium rectifier VS 18/12
91a	Wire-wound resistor (set at factory)
92	Interlock
93	Switch
94	Switch
95-96	Capacitor KBGI-1; 400 V, 0.05 microfarad ± 10%
97	Choke
98	Capacitor KSO-5, 500 V, 3300-10,000 micromicrofarad
99	Choke
100-101	Capacitor KBG-I, 400 volts, 0.05 microfarad ± 10%
102	Capacitor KSO-5, 500 V, 1500 micromicrofarad ± 10%
105	Capacitor KBGI-1, 400 V, 0.05 microfarad ± 10%
106	Resistor PE, Type II, 2000 ohm ± 10%
107	Capacitor KSO-5, 500 V, 3300 micromicrofarad ± 10%
108	Electromagnetic Relay
109	Fuse: 20 A at 127 V or 10 A at 220 V

CHARACTERISTICS OF HIGH-FREQUENCY CHOKE

Number on Circuit Diagram	Number of Turns	Wire		Length or Core, in mm
		Type	Dimensions in mm	
26	200	PE	0.31	30
35	160	PE	0.31	35
50-51	110	PE	1.0	30

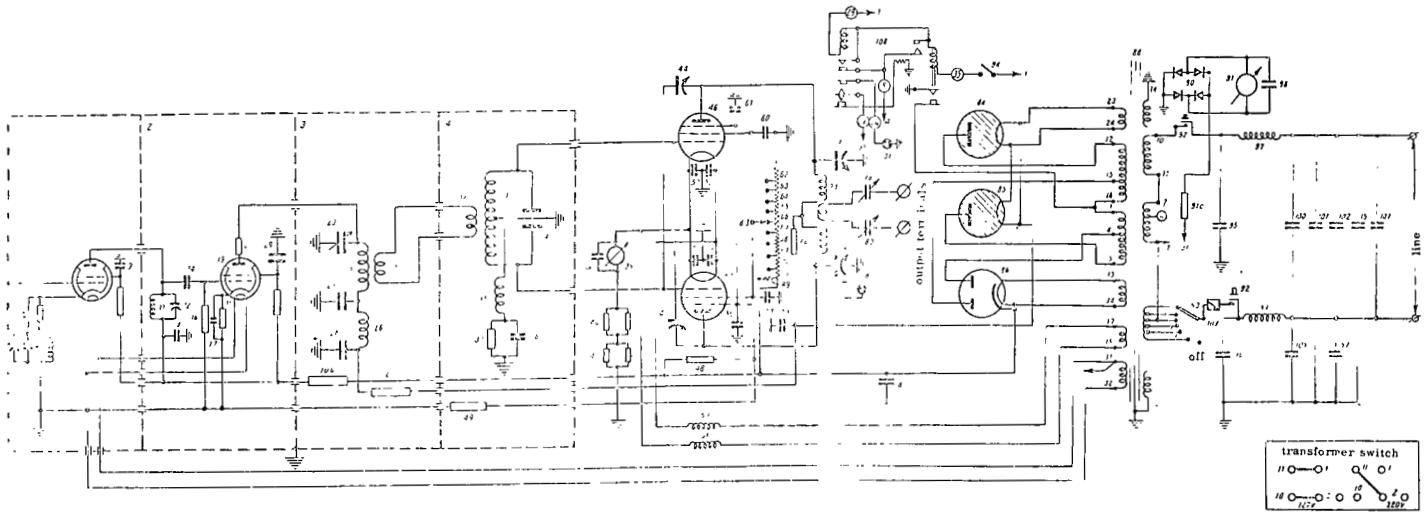


Fig. 209. Schematic Diagram of DKV-1 Apparatus for Inductothermy.

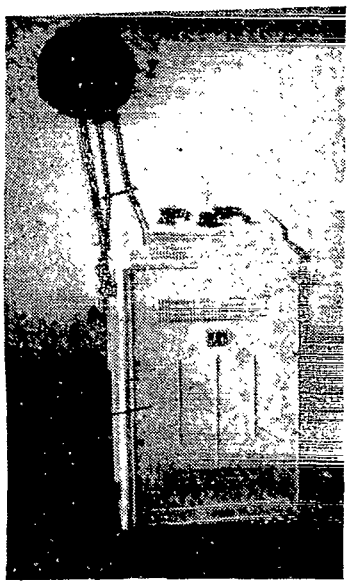


Fig. 210. General View of DKB-1 Apparatus for Inductothermy.

The design of the apparatus is as follows. It is mounted in a metal cabinet with a sloping front control panel. For convenience in moving, it is fitted with casters. All four sides of the cabinet can be removed. However, in conventional usage (during routine maintenance or checking the operation of the apparatus) only the front and back of the cabinet are removed. The latter are fitted with interlocks.

A general view of the apparatus is shown in Fig. 210. The cabinet 1 supports a sturdy movable support, the electrode holder, on which is mounted a disk electrode 2. On the back of the cabinet is a socket for plugging in the electrodes. The power cord is fitted with filter 3 for suppressing radio interference.

The panel of the apparatus (Fig. 211) is fitted with equipment for monitoring and control; at the top are the meters, with the voltmeter 2 at the left and the milliammeter 5 at the right. At the bottom center is switch 4 for the high voltage and on both sides of it are the lenses of the pilot lights; at the left is 3 which indicates that the circuit is ready for the high voltage to be switched on, and at the right is 6 which indicates that oscillations have appeared in the output amplifier. At the bottom of the control panel at the left is knob 1 for the voltage compensator, while in the center is knob 8 for the trimming capacitor, and at the right of that is knob 7 for the power regulator.

Inside the apparatus (Figs. 212 and 213), the components are mounted in separate, completely shielded units (additional shielding material is located inside of several of the units as well) which are arranged on three shelves.

After removing the front of the cabinet (Fig. 212), access can be gained to the top and bottom shelves. The bottom shelf is covered by a shield with two openings for adjusting the capacitors in the oscillating circuit of the master generator (the right-hand hole) and the intermediate amplifier (the larger hole at the left). /24
Figure 212 shows this shield removed.

On the bottom shelf at the left-hand side is power transformer 8; above this transformer is the panel for connecting the transformer section to the line voltage at 127 or 220 volts. To the right of the transformer are tubes 5 (gas-filled and kenotron recti-

fiers) and behind them is vitreous resistor 11.

On the middle level, on a special compartment on the right-hand side, are the following parts which are mounted on a vertical board: quartz crystal 8, below it coil 10 of the cathode circuit, and the capacitor (ceramic) for the same circuit, which is mounted on the end of the coil. Behind these are the bias resistors for the cathode circuit and the blocking capacitor for the same circuit, as well as the resistors and capacitor for the screen grid circuit of the tube in the master generator, and the tube panel.

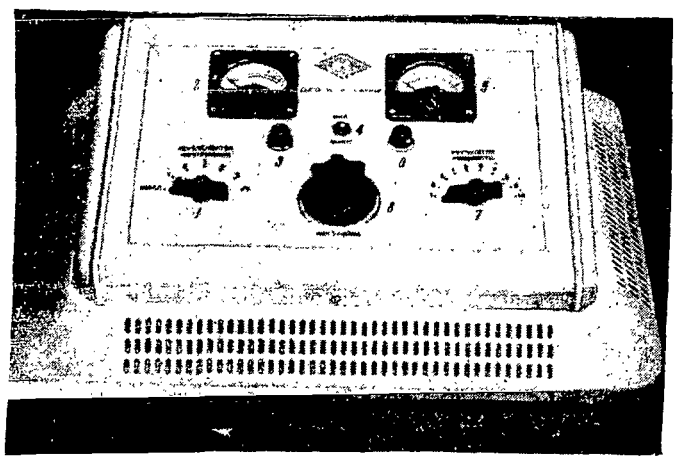


Fig. 211. Location of Parts on the Control Panel of the DKV-1 Apparatus for Inductothermy.

In the shielded area at the right there is an opening through which a screwdriver can be inserted to adjust the value of the capacitor for the cathode circuit (after removing the side of the cabinet first). The cathode circuit of the master generator has been adjusted at the factory and does not need to be changed during use.

In the middle shielded compartment are tube 12 and below it the anode circuit 4 of the master generator, consisting of a coil and a ceramic capacitor (marked 12 in the circuit) which is mounted on the end of its core.

On a circuit board at the left are resistors (marked 16, 18, and 30 in the circuit) and capacitors (marked 13, 14, 17, and 29 in the circuit), which are used in various circuits of the intermediate amplifier, as well as the corresponding tube panel. In the lowest section there is a vitreous resistor 15 in the power supply for the excitor and the screen grid of the intermediate amplifier (marked 106 in the circuit).

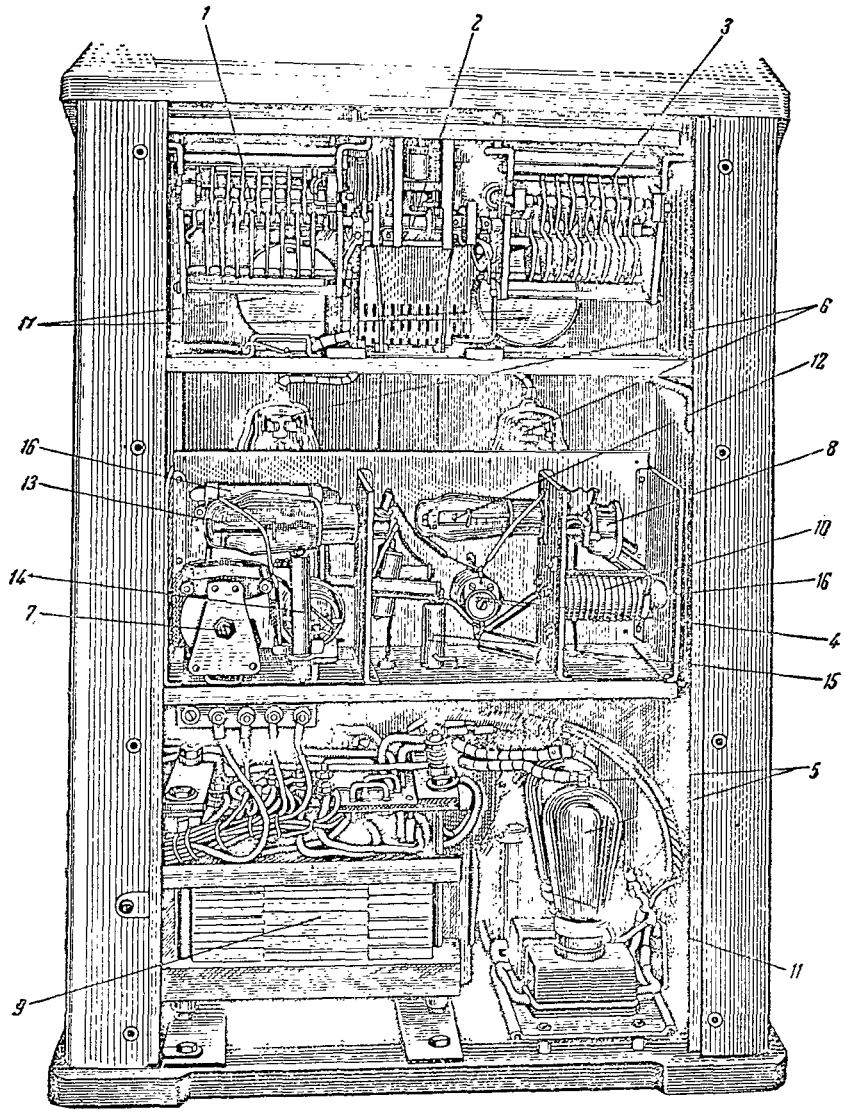


Fig. 212. Location of Parts in the DKV-1 Apparatus for Inductothermy; View With Front of Cabinet and Shielding Removed.

In the shielded compartment at the left-hand side is tube 13 /24' of the intermediate amplifier and its anode circuit, which consists of coil 14 together with the connectors (marked 24 and 25 in the circuit) as well as adjustable air-gap capacitor 7 (marked 20 in the circuit); there is also a high-frequency choke 16, and a resistor and capacitors in the power section of the anode circuit (marked 23, 26, 27, and 28).

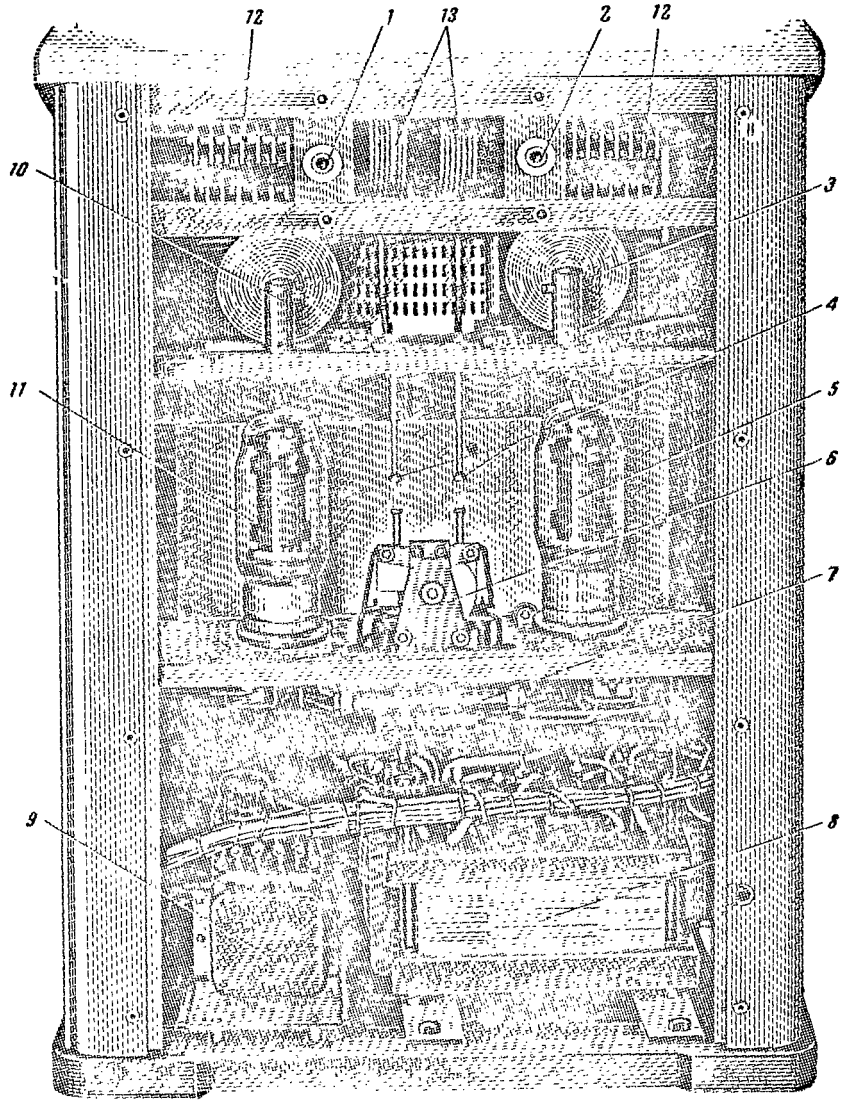


Fig. 213. Location of Parts in the DKV-1 Apparatus for Inductothermy; View With Back of Cabinet Removed.

From these terminals, a shielded wire runs downward below the chassis to the back of the cabinet, where it enters the shielded compartment for the grid circuit of the output amplifier (see Fig. 213; in this figure, the shield which is located between tubes 11 and 5 has been removed). In this compartment there is a coil (marked

33 in the circuit) and variable capacitor 6 (marked 34 in the circuit), which is adjusted through the corresponding opening in the center of the shield.

At the top, above the compartment for the grid oscillator circuit of the output amplifier, are the neutrodyne capacitors 4 which are in the shape of small disks with air gaps between them (marked 44 and 45 in the circuit). To either side of the compartment are tubes 5 and 11 of the output amplifier.

Lower down on the chassis are the high-frequency choke (marked 35 in the circuit) and bias resistor 7 (marked 37 in the circuit) blocked by a capacitor (marked 36 in the circuit) as well as high- /246
frequency chokes (marked 50 and 51 in the circuit) for the heater circuit for the output tubes. In addition, there are several parts of the output amplifier circuit located here as well. All of the parts mentioned are covered by a shielded cover (this cover has been removed in Fig. 213).

On the top shelf, immediately above the tubes, are capacitors 3 and 10 for the anode oscillator circuit of the output amplifier (marked 77 and 78 in the circuit). The capacitors are in the form of two metal disks with an air gap between them. These capacitors are adjustable, have a low value and make it possible to adjust the circuit for a frequency of 13.56 MHz, as well as to make it symmetrical. The basic capacitance of the oscillating circuit is produced by the interelectrode capacitance of the tubes themselves.

Above and behind the capacitor disks of the anode circuit are sockets 1 and 2 for the terminals of the electrode cables. Between them is coil 13 for the anode oscillator circuit of the output amplifier, divided into two parts between which run the wires connected to the therapeutic circuit (marked 75 in the circuit). On the top shelf (see Fig. 212) are air-gap capacitors of variable value for therapeutic circuits, located separately in two sections, 1 and 3 (in Fig. 213, these sections are marked 12). In the center between these sections is a conical reducing gear activated by the knob on the control panel.

The apparatus is operated as follows: before plugging the apparatus into the wall, it is necessary to be sure that the knob of the voltage compensator is set at the far left (off) position, the high-voltage switch is set to the "off" position, and the power regulator knob is at the zero position. After this check has been made, the plug can be inserted into the wall socket where the apparatus is to be used. Then the ends of the electrode cable are plugged into the sockets on the apparatus. It is important to remember that when plugging in the apparatus, one must be careful to set the power regulator knob to the higher divisions of the scale only after the electrode has been placed on the patient and the ends of the cable have been plugged into the apparatus. Operation without load is extremely harmful for the apparatus. After this, the

apparatus can be turned on by turning the voltage compensator knob clockwise. The compensator knob is turned to the right until the voltmeter needle reaches the position marked by the red line, which corresponds to the nominal voltage for operation of the apparatus. It is then necessary to wait for the time-delay relay to operate; a white light on the control panel indicates that the relay is operating.

Then the high voltage can be turned on. This causes the pilot light to go on. After the voltage has been admitted to the circuit, it is necessary to check the resonance of the therapeutic circuit. To allow a small amount of power to flow in the circuit, the power regulator is set to the fourth or fifth position and the compensator knob is then rotated to reach the resonance setting. The resonance position is established by the maximum deviation of the milliammeter needle. If the latter moves too little and the position of resonance cannot be found, the power regulator is shifted to the 6-7 position. After the therapeutic circuit has been placed in resonance, it is possible to proceed with the power regulation; this means that the power regulator knob must be set to the next operating position so that the patient will not feel a noticeable sensation of heat.

The power applied to the patient circuit in inductothermy is adjusted by feel and checked against the readings of the milliammeter, which is connected to the power circuit for the tubes in the output amplifier. By using the readings of the milliammeter, /247 similar dosage conditions can be employed in subsequent treatments.

When the treatment is complete, the power regulator knob is returned to the initial position, the high voltage is switched off, and the voltage compensator knob is turned to the extreme left position. Only then can the electrodes be removed from the patient. When performing treatment, one electrode must not be removed before the other without cutting off the line voltage; however, it is important to check before each treatment to be sure that the proper values have been set and to adjust them if necessary.

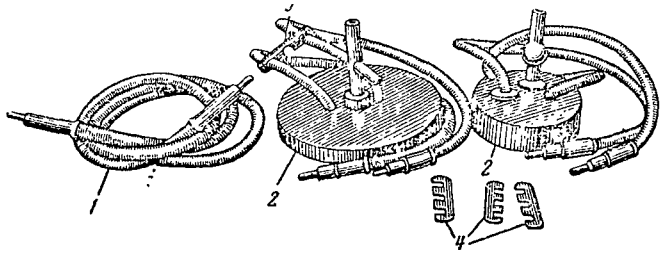


Fig. 214. Set of Electrodes Supplied With the DKV-1 Apparatus for Inductothermy.

The following precautions should be followed when giving treatment. Excess clothing should be removed from the patient's body. All metal objects, (watches, hair pains, buckles, etc.) located in the vicinity of the region which is going to be treated by the magnetic field must be removed. Treatment should be carried out only on a wooden surface (table or couch). The possibility of the patient's coming in contact with any grounded metal objects must be avoided (such objects as the cabinet of the apparatus, heating pipes, etc.).

When applying inductothermy to the extremities, the cable electrode is used most often; it is wrapped two or three times around the corresponding part of the extremity so that the free ends to be connected to the apparatus are at least 1 m long. The diameter thus produced should allow an air gap of no more than 1 cm between the coils and the surface of the skin. The turns of the coil are fixed in place by means of insulating spacers provided by the apparatus, which are slipped over the cables to hold them in place.

When treating certain areas of the trunk or head, either a flat spiral made of the electric cables or a disk electrode can be used. The size and shape of the spiral depends on the areas to be treated, taking into account the necessity for having the free ends at least 1 m long. The turns of the spiral are held in place by the spacers. The disk electrode used for treating the trunk is a large one, while that used for the face or head is small.

The factory states that when the DKV-1 apparatus is being used, the space between the turns of the coil or between the disk electrode and the surface of the body of the patient should not exceed 1 cm. If this precaution is not observed, the apparatus will work abnormally. In addition, the electrodes should not be removed from the patient when they are charged, either before or after the treatment.

The apparatus delivers full power when the milliammeter reads 450-480 mA. As the current increases further, the power drops and the apparatus operates abnormally.

A general view of the electrodes is shown in Figure 214: 1 is the electrode cable, 2 the large disk electrode, 3 the small disk electrode and 4 the spacers for the cable.

The following parts are provided with the apparatus:

1. Disk electrode, 200 mm in diameter (1).
2. Disk electrode, 300 mm in diameter (1).
3. Electrode cable with terminal (1).
4. Insulated spacer for cable (4).
5. Vacuum tube for output amplifier, G-471 (GK-71) (4).
6. Vacuum tube for output amplifier, G-807 (2).
7. Vacuum tube and output amplifier, 6F6S (2).
8. Gas-filled rectifier VG-129 (VG-9) (4).

9. Kenotron 5Ts3S (5Ts4S) (2).
10. Line filter (1).
11. Fuses for 10 or 20 amperes (2).
12. Technical description and certificate for apparatus.

No additional changes need to be made in the circuitry of the generator for normal operation of the apparatus. The adjustments have been made at the factory and the variable capacitors are fastened in or set to the zero position. When a new instrument to be operated for the first time (especially when it has been in transport for long periods of time) the setting of the capacitors should be checked.

As we can see from the description, the variable capacitors are located in the anode circuits of the master generator and the intermediate amplifier (capacitors 12 and 20 in the diagram); access to them is gained through the corresponding openings in the shield which covers the compartment containing these units.

The variable capacitors (marked 3 in the circuit) connected to the quartz cyrstal should not be touched during operation.

Capacitor 34 in the aligned circuit of the output amplifier is adjusted through the opening in the shield. The capacitors in the anode circuit) marked 77 and 78 in the circuit) as well as the neutrodyne (marked 44 and 45 in the circuits, see Fig. 213), are adjusted by changing the distance between the plates after loosening the set screws.

Adjustments should be carried out with the aid of a wavemeter and are required after only after setting up the apparatus or replacing or correcting some defect in it (and occasionally after replacing a vacuum tube).

The adjustment should be made carefully with all shields in place and with the front and rear covers of the cabinet removed (the sides remain in place).

§2. APPARATUS FOR INDUCTOTHERMY DKV-2

In 1956 the Union Factory of the EMA devised a new model of the apparatus for inductothermy, which was much more completely equipped for suppression of radio interference than the DKV-1. The basic features of the apparatus remained essentially unchanged. The output power, as described in the certificate provided with the apparatus, is 250 $\pm$ 50 watts. The oscillator frequency of the generator is 13.56 MHz, with variations from within the limits of $\pm$ 0.05%.

In 1960, the DKV-2 apparatus was first produced by the Volgograd Factory for Medical Equipment.

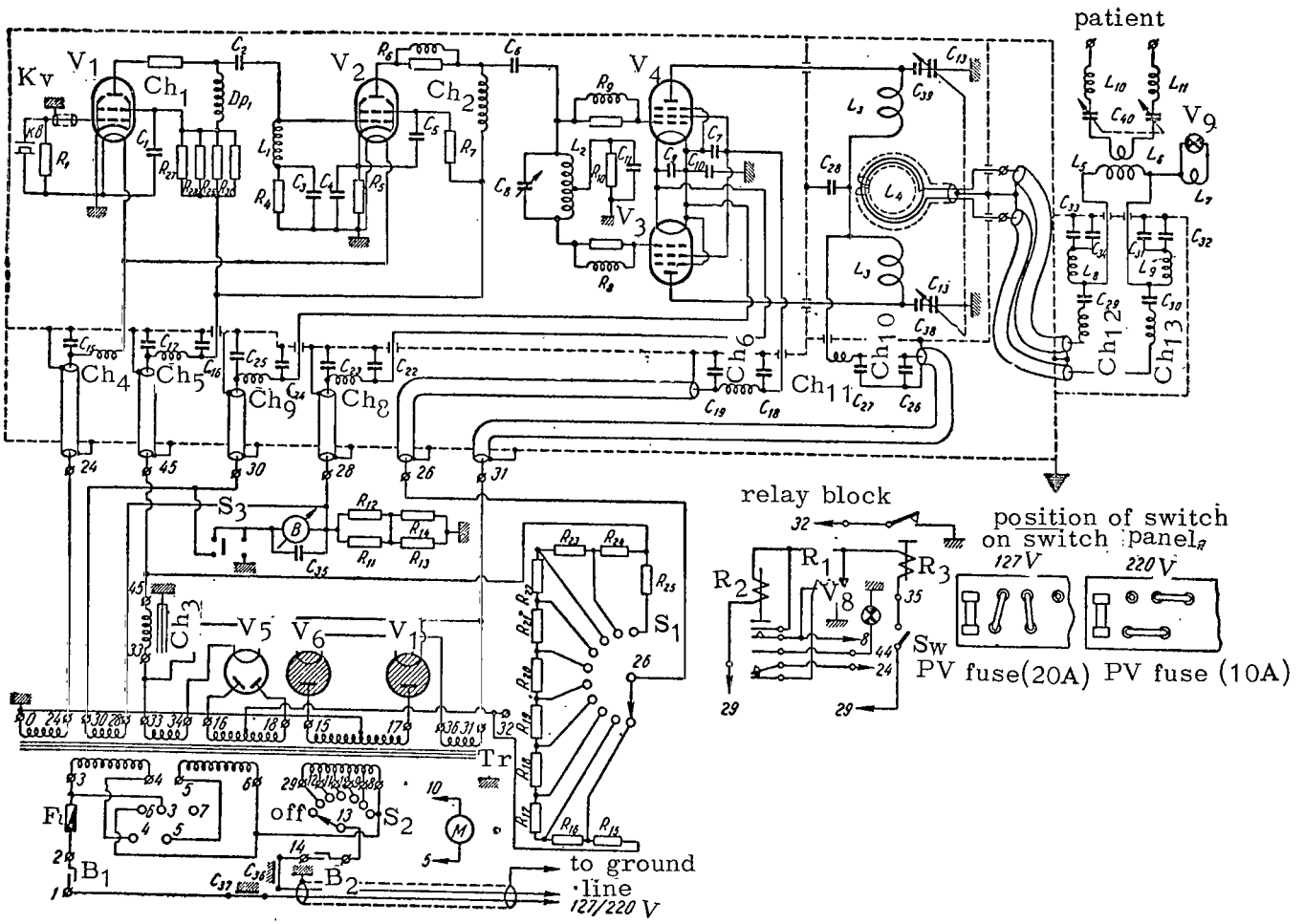


Fig. 215. Schematic Diagram of DKY-2 Apparatus for Inductothermy.

The schematic diagram of the apparatus remained essentially /250
the same although some design changes were made in the overall assembly of the apparatus.

The following is a description of the apparatus as produced by the EMA Factory.

The schematic diagram of the apparatus is shown in Figure 215. The apparatus consists of five sections: (1) master generator, (2) intermediate amplifier, (3) output amplifier, (4) therapeutic circuit and (5) power supply.

The master generator uses a 6P3 tube (V_1) with quartz stabilizer Kv in the control grid circuit. The quartz grid is shunted by resistor 1, which forms a bias from the constant component of the grid current. The anode circuit of the generator consists of coil 1 and the interelectrode capacitances of the tubes which are in parallel with it (the output capacitance of tube V_1 and the input capacitance of the next tube in the circuit, V_2), and is then modified to a frequency which somewhat exceeds the frequency of the quartz stabilizer. The latter has a frequency equal to half the nominal, or 6.78 MHz.

The generator has a parallel power supply. The power circuit is blocked by choke 1, while the oscillator circuit contains a separating capacitor 2.

The anode circuit contains resistor 2 which prevents the occurrence of parasitic oscillations at other frequencies. The anode and screen grids are powered through quenching resistors 27 and 30; at high frequency, the grid is connected to the cathode by capacitor 1.

The intermediate amplifier or frequency multiplier operates with a 6P3 tube (V_2). The tube grid is linked directly to coil 1 of the oscillator circuit of the exciter. The coil circuit contains bias resistor 4 which is shunted by capacitor 3. Bias produced by the constant component of the cathode current of the tube is formed across resistor 5, shunted by capacitor 4.

The anode oscillator circuit of the amplifier consists of coil 2, variable capacitor 8, the the interelectrode capacitances of tubes V_2, V_3 and V_4. The circuit is set to the operating frequency of the generator, 13.56 MHz. The amplifier uses a parallel power circuit. The latter contains a blocking choke 2 and the separating capacitor 6. To make a changeover to a two-stage circuit, the center tap of coil 2 in the output stage of the generator in the anode circuit is grounded.

The anode circuit of the tube contains an antiparasitic resistor 6. To reduce the loss of energy, a few turns of wire are mounted above the resistor to form a small inductance connected in parallel

with the resistance. The screen grid is powered through the quenching resistor 7 and is connected to the cathode by capacitor 5.

The output power amplifier operates in a two-stage circuit using GK-71 tubes (V_3 and V_4). The grids of the tubes are connected to the oscillator circuit of the frequency multiplier through antiparasitic resistors 8 and 9, each of which is shunted by a small inductance. The center tap of coil 2 is connected to bias resistor 10, shunted by capacitor 11.

The anode oscillator circuit of the amplifier consists of inductance coil 3, double adjustable capacitor 13, the interelectrode capacitances between the amplifier tubes, and capacitors 38 and 39 (these capacitors prevent short-circuiting to ground of the power supply circuit in case capacitor 13 fails). The circuit operates at a frequency of 13.56 MHz. The power for the circuit is arranged in series through the center tap of coil 3. The anode current passes through the tubes and goes from the cathodes of the tubes through a wire supplying the filament and on through resistors 11 and 14; the ground returns it to the power source. The voltage drops across resistors 11 and 14 produce the bias on the tube grids.

The screen grids of the tubes are powered from a stepped potentiometer (resistors 15-25). The output power of the amplifier is controlled by the change in the voltage in the screen grids. /25

The screen grids are connected with the cathodes by capacitor 7 for high frequency. The shielded grids are connected directly to the tube cathodes. Capacitor 9 smooths the high-frequency potential in the filament wires. The filaments of the tubes are grounded at high frequency by capacitor 10.

The length between the oscillator circuit of the amplifier and the therapeutic circuit is accomplished by means of an intermediate circuit consisting of shielded terminal 4, coils 5 connected with the therapeutic circuit, and the high-frequency filter connected between them. The filter consists of induction coils 8 and 9, chokes 12 and 13, and capacitors 29 and 34. The shielding of terminal 4 along with the filter ensures that no oscillations of higher harmonic frequencies, contained in the anode circuit of the amplifier, will reach therapeutic circuits, thereby limiting the radiation of radio interference by the circuit. The second and other even harmonics are suppressed by electrostatic screening of terminal 4. The third harmonic is suppressed by means of a filter.

The high-frequency filter (Fig. 216) consists of a number of circuits which are in resonance at certain frequencies. The series of circuits composed of half the turns in circuit 4, choke 12 and capacitor 29 (or, similarly, half the turns of circuit 4, choke 13, and capacitor 30) is in resonance at the basic frequency of the generator. The circuits which consist of coil 8 and capacitors 33 and 34, (or coil 9 and capacitors 31 and 32) is in resonance

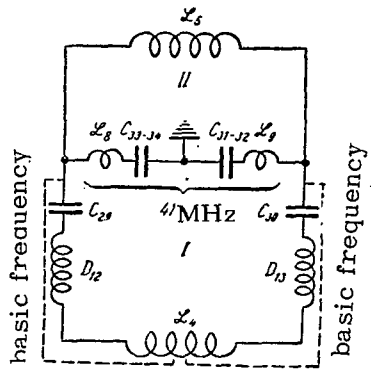


Fig. 216. Schematic Diagram of High-Frequency Filter in the DKV-2 Apparatus.

with the third harmonic of the basic frequency (41 MHz). These three circuits form the system shown in Figure 1. In addition, the filter contains an oscillator circuit which is formed by coils 8 and 9 and capacitors 31 and 34 along with coils 5, which is represented by II and operates at a basic frequency. As a result, the oscillations at the basic frequency occur without any weakening in subsequent circuits (Ch 12-13 and C 29-30) and reach the oscillator circuit II; they then pass through circuits 5 and into the therapeutic circuit. On the other hand, the third harmonic is damped in circuit I (L_8 = L_9 and C 31-34) and forms a resistance which is low for the third harmonic. In addition, in order to reduce radio interference from the even harmonics of the anode currents, the center tap of coil 3 is grounded to the shield through capacitor 28.

Coil 5 is connected to terminal 7 which is connected in turn to pilot light 9. The therapeutic circuit consists of connecting coil 6, capacitor 4 (variable) two inductances 10 and 11 which suppress the formation of the third harmonic in the circuit, and the output sockets for connecting the electrode cable.

Setting the therapeutic circuit in resonance with the frequency of the generator is accomplished by means of adjustable capacitor 40. The indicator for the setting is a meter (voltmeter B). With the aid of switch S_3, the latter can be connected in parallel either with the filaments of the generator tubes (when the instrument /252 acts as a voltage indicator showing the voltage near the generator) or in parallel with resistors 11 and 14 which are connected in the cathode circuits of the tubes of the output stage. In this case, the readings of the instrument are directly proportional to the cathode current of the tubes and the instrument is used as a setting indicator.

The power supply consists of a power transformer and two rectifiers. The gas-filled rectifier tubes (V_6-V_7) have an output voltage of 1400-1500 volts and supply the anode circuit of the output amplifier. The rectifier using kenotron V_5 and filter choke Dr_3, with an output voltage of 400-500 volts, feeds the circuit of the master generator and a frequency multiplier and the screen grids of the output amplifier through the regulating potentiometer (resistors 15-25).

The transformer has the following windings: two primaries, a voltage compensator winding, two step-up windings for powering the rectifiers, two filament windings for the 6P3 and GK-71 tubes, and two filament windings for the gas-filled rectifiers and kenotron.

Depending on the magnitude of the voltage in the line (127 or 220 volts), the ends of the primary winding are arranged as shown in the diagram.

In the control block, there is a group of relays which is completley analogous to those used in the DKV-1 apparatus, a fuse, an interlock for the cabinet sides, etc. One different feature of the DKV-2 is the presence of electric motor (M) for the fan to cool the parts inside the cabinet, whose natural cooling is complicated by the considerable amount of shielding and the presence of filters for suppressing radio interference, (the shielding is represented by a dashed line on the diagram). The shielding of all high-frequency parts means that the radiation of radio interference will occur only through the wires which supply that part of the apparatus and through the wires leading to the therapeutic circuit. To prevent this, all of the wires which power the high-frequency section are provided with noise-suppressing filters consisting of high-frequency chokes (4-11) connected in series and a capacitor (15-26) connected in parallel and grounded to the shield. The portions of the wires which run between the shield and the filters are also shielded (the filter which is used in the therapeutic circuit has been described previously). In addition, in order to suppress radio interference in the line cord, the latter contains capacitors 36 and 37.

The operation of the DKV-2 differs from that of the DKV-1 in that the voltage is immediately applied to the gas-filled rectifier tubes when the apparatus is plugged in and goes from there to the anode circuit of the output stage, so that the entire electrical part of the apparatus is at high voltage. This must be taken into account when using it or when adjusting the apparatus. The gas-filled rectifiers are not loaded at this time, since the tubes in the output stage are closed by the negative potential on the screen grids which comes from the initial point on the voltage divider (resistor 15-25), and the center tap of the kenotron rectifier (contact 32) is not grounded. After relay R_3 operates (when the high-voltage switch on the control panel is moved to the "on" position) the positive potential is placed on the screen grids from this voltage divider, thus starting the operating regime of the apparatus. It is only at this time that a current appears in the gas-filled rectifier circuit.

Specifications for Schematic Diagram of DKV-2 Apparatus

V_1, V_2	Vacuum tube 6P3S
V_3, V_4	Vacuum tube GK71
V_5	Kenotron 5Ts3S
V_6, V_7	Gas-filled rectifier VG129
V_8, V_9	Miniature vacuum tube MN-14 E-10.6 V x 0.28 A

Resistors

/253

R_1	VS-1 100 kohm ± 20%
R_2	VS-2 51-100 ohm ± 20%
R_4	VS-2 18 kohm ± 10%
R_5	TE-15 250 ohm ± 10%
R_7	VS-2 16-51 kohm ± 20%
R_6, R_8, R_9	VS-2 51-100 ohm ± 20% Silver wire, 1 mm, 130 mm long, PEL or MM, mounted on resistor.
R_{10}	PE-II 2 kohm ± 10%
R_{11}-R_{14}	PE-I 100 ohm ± 10%
R_{15}-R_{19}	PE-II 2 kohm ± 10%
R_{20}-R_{23}	PE-II 4 kohm ± 10%
R_{24}	PE-II 2 kohm ± 10%
R_{25}	PE-I 500 ohm ± 10%
R_{26}	PE-III 1 kohm ± 10%
R_{27}-R_{30}	VS-2 21 kohm ± 10%

Capacitors

C_1	KPGI 600 V, 0.01 µf ± 20%
C_2	KSO-5, 500 V, 470 nf ± 20%
C_3 -C_5	KBGI, 600 V, 0.01 µf ± 20%
C_6	KSO-5, 500 V, 470 nf ± 20%
C_7	KSO-5, 500 V, 5100 nf ± 20%
C_8	Air-gap capacitor
C_9 ,C_{10}	KSO-5 500 V, 5100 nf ± 20%
C_{11}	KBGI, 600 V, 0.01 µf ± 20%
C_{13}	Air-gap capacitor
C_{15}-C_{25}	KBGI, 600 V, 0.01 µf ± 20%
C_{26}-C_{28}	KVKT-5, 680 nf ± 10%
C_{29}-C_{30}	KVKT-19, 47 nf ± 10%
C_{31}-C_{34}	KVKT-17, 100 nf ± 10%
C_{35}	KBGI, 600 V, 0.01 µf ± 20%
C_{36}-C_{37}	KBT, 1000 V, 20 A, 0.025 µf ± 20%
C_{38}-C_{39}	KVKT-5, 680 nf ± 10%
C_{40}	Air-gap capacitor

Inductances

L_1, L_2, L_3	Inductance Coil
L_4	Circuit Coil
L_5	Inductance Coil

L_6 ,L_7	Circuit Coil
L_8 ,L_9	Inductance Coil. Silver wire, 1mm, MM, 4 turns; internal diameter of coil 6 mm, 1.5 mm between turns.
L_{10},L_{11}	Inductance coil.
Ch_1 ,Ch_2	Chokes 2.5-4 mh. PELBO wire, 0.25 mm. 6 sections wound on core.
Ch_3	Choke. PEL wire, 0.38 mm, 2 x 1500 V.
Ch_4 -Ch_9	Choke, PEL wire, 1.5 mm, number of turns equal 12. Internal diameter of turns 15 mm, 2 mm apart.
Ch_{10},Ch_{11}	Choke
Ch_{12},Ch_{13}	Choke, PEL wire, 1 mm. 12 turns. Internal diameter 20 mm, 2 mm between turns.

Kv	Quartz crystal 6780.0 kHz	R_2, R_3	Electromagnetic relays
V	Voltmeter E-421, 0 50 V	M	Electric Motor DAG-1
F	Fuse, PV 10 A or 20 A	P_1,P_2,P_3	Switches
R	Thermal Relay	Sw	Switch
		B_1, B_2	Interlock

The design of the apparatus is as follows. The DKV-2 is mounted in the same cabinet as the DKV-1 (see Fig. 210). At the top of the control panel at the center is the meter, while at the left is a switch for it ("voltage control", "adjustment control"); to the right is the "generator switch" which is the same as the high-voltage switch in the DKV-1. However, the purpose of it (as mentioned above) is somewhat different. It turns on the supply voltage to the screen grids and not to the anode circuit of the power amplifier tubes. Below this are the pilot light lenses which have the following significance: the one on the left indicates that the time-delay relay is operating, while the one on the right indicates that high-frequency oscillations are being transmitted to the output of the generator. At the bottom center is the knob for adjusting the capacitor controlling the therapeutic circuit, while on the right is the knob for the power regulator; to the left of these is the voltage compensator knob.

The arrangement of the parts within the apparatus is shown in Figure 217 (internal view of the apparatus with the front panel removed). At the bottom center is transformer 1, to the left is kenotron 3 and gas-filled rectifiers 2 in the center (to the left and behind, electric motor 4 for the ventilator fan can be seen); /254 to the right is low-frequency choke 5 which is connected to the kenotron rectifier circuit. In the center of the cabinet is a large shielded box 7, covered on all sides. In Figure 217, the front of this box has been removed to provide access to the equipment, which is in turn enclosed in still smaller shielded boxes.

In the middle of the cabinet on the left-hand side are the parts of the master generator (in a shielded box 8) and the inter-

mediate amplifier, as well as the grid circuit of the output amplifier.

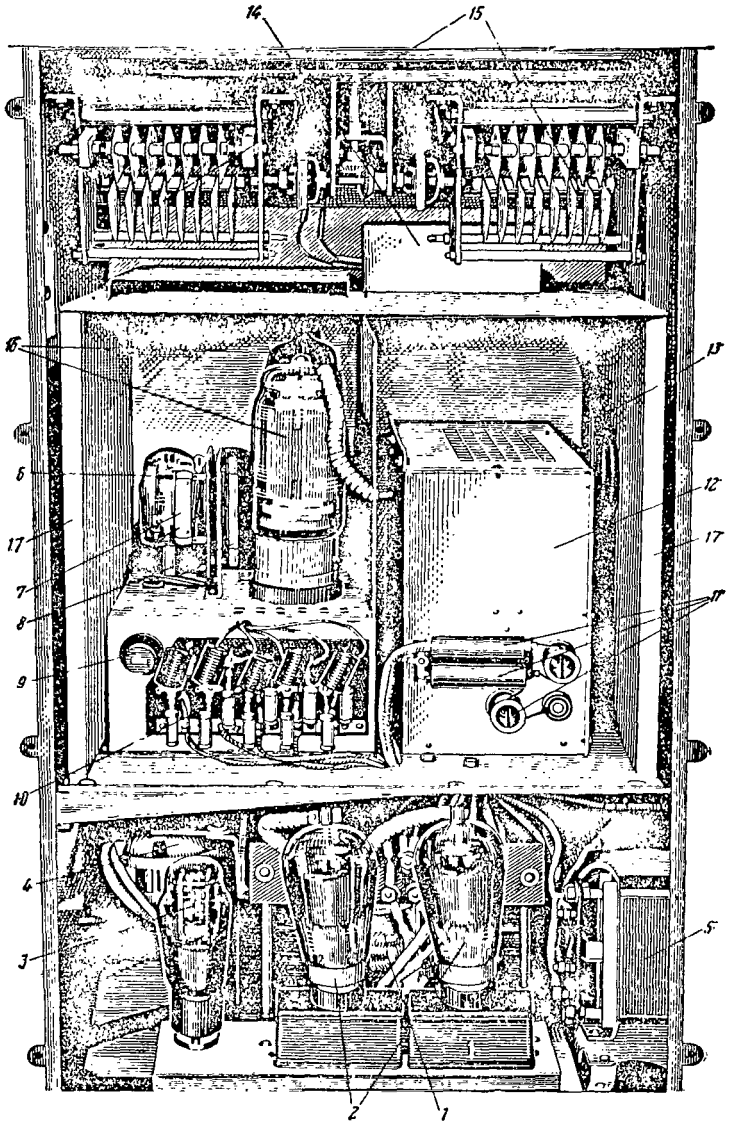


Fig. 217. Arrangement of Parts in the DKV-2 Apparatus.

Above this compartment is tube 6 of the master generator, and /255 behind it the tube of the intermediate amplifier. At the right are the tubes of the output amplifier 15, and between them is panel 7 carrying the resistors which are connected to the power circuits

for the anode of the master generator and the screen grids of the output tubes. On the side of this compartment is the quartz stabilizer knob 9 and panel 10 with coils and capacitors for the high-frequency filters which are connected to the supply wires (ch 4-9 and C 15-25 in the circuit). The rotor of the capacitor (8 in the circuit) for the grid circuit of the output amplifier is located in this compartment and can be reached through opening 6 in the back of the compartment.

On the right is the shielded compartment 12, which contains the parts of the anode circuit of the output amplifier (coils and capacitors). The rotor of the capacitor (marked 13 in the circuit) can be rotated by inserting a screwdriver through the back of the cabinet. On the front of this compartment is panel 11 wih chokes and capacitors for the high-frequency filter, connected to the line which powers the anode circuit of the output amplifier.

In the top of the cabinet are compartment 14 (protected by a shield) for the high-frequency filter (13 marks the shielded leads which run to it from the anode circuit) and capacitor 15 of the therapeutic circuit.

If the back of the cabinet is removed, the following parts can be seen: at the bottom (on top of the power transformer) there is a panel with contacts for adjustment and switching the apparatus to 127 or 200 volt current; on the right is the relay block and to the right of this the electric motor driving the ventilator. The entire center of the apparatus is occupied by the back of the compartment which shields the generator section of the apparatus. (In Fig. 217, this box is represented by 16). The back of this box has two openings, through which the grid and anode circuits of the output circuits of the amplifier can be adjusted. At the top of the apparatus are a housing for the high-frequency filter, the capacitor for the therapeutic circuits, the circuit coils (all of these parts can be seen in Fig. 217), and a socket for connecting the ends of the cable from the electrodes.

Setting up the apparatus for performing treatment is essentially the same as for the DKV-1 apparatus. There is a certain degree of difference introduced by the presence in the DKV-2 of one measuring device, which must be set to the "voltage check" position when the apparatus is plugged in, but must be put to the "adjustment check" after using the compensator knob to set the normal supply voltage. The order in which the apparatus is set up is the following: (a) Check to be sure that the pointers of the voltage compensator and power regulator are turned counterclockwise all the way and that the generator switch is in the "off" position. (b) The voltmeter switch must then be set to the "voltage check" position. (c) The plug is inserted in the wall socket. (d) The knob of the voltage compensator is moved to the first position (when the voltmeter needle shows that the apparatus has been turned on), and is then advanced to the position corresponding to the

deflection of the needle within the limits of the colored area on the scale. (e) Wait several minutes until the relay operates and the left-hand pilot light goes on. (f) Switch the voltmeter to the "adjustment check" position; turn the generator switch to the "on" position; the right-hand red lamp should light up to show the presence of high-frequency oscillations in the circuit. (g) turn the knob for adjusting the therapeutic circuit slowly, in order to obtain the maximum deflection of the indicator needle. (h) Use the power regulator knob to set the required amount after checking to be sure the therapeutic circuit is in order.

The meter readings at maximum needle deflection are proportional (to a certain degree) to the power absorbed by the patient. /256

In carrying out treatment with the DKV-2 apparatus, the factory recommends that a gap between the cable spiral or disk electrode and the body of the patient be kept at 1 cm. This means that the maximum power of the apparatus can be used at the tenth position of the power switch knob. If the conditions of the treatment require that the gap exceed 1 cm (for example, if a plaster cast is applied), an undesirable thermal condition will exist in the generator tubes, and the cable itself or disk electrode may over-heat. Under these conditions, the factory recommends that the apparatus be used at settings which do not exceed the 30th division of the scale, and alo that the overheating of the cable or disk electrodes be carefully watched. A gap of less than 1 cm may suffice from the standpoint of the operation of the apparatus, but it produces heat on the surface of the tissue below it, which is undesirable as we have pointed out above.

The set of parts which are supplied with the DKV-2 is the same as that for the DKV-1, with the exception of vacuum tubes (in this case, there are 4 6P3 tubes instead of 2 T-807 tubes and 2 6F6 tubes).

Following are some remarks on adjusting the apparatus. The apparatus must be adjusted as soon as it is received from the factory and each time that new vacuum tubes have been installed in the high-frequency section. It is important to keep in mind that high voltage appears all through the apparatus at the same time that it is plugged into the line, and necessary safety measures must be taken (see Chapter V, Part 2).

The following tools are necessary to make adjustments: a long handle made of insulating material (ebonite, plastic, etc.), a screwdriver with a handle made of nonconducting material, and a neon bulb. It is necessary to use only one hand when making adjustments and not to touch the other hand either to other objects or especially to the cabinet of the apparatus.

When the front or the back of the cabinet has been removed, and the front of the shield covering the generator unit has been removed, the interlock contacts must be closed. All the tubes

and the quartz crystal must be installed, and the anode covers for the generators must be put in place; the anode covers of the gas-filled rectifiers are not put on. The apparatus is switched on as described above until the therapeutic circuit has been adjusted and the power regulator knob has been set to the ninth position (this will place the maximum voltage on the screen grid tubes and oscillations will appear in the output amplifier). Now, by turning a screwdriver with an insulated handle (having inserted it through the opening in the back of the shielded compartment), the rotor of variable capacitor can be moved to make the pointer on the meter show the maximum deflection (approximately 12 volts). The apparatus must be set to "adjustment check". The apparatus is then turned off and a check is made for an absence of voltage on the covers which must be placed over the anodes of the gas filled rectifier tubes. To do this, each of the caps must be placed on the top of the shielded housing using gloves made of insulated material. If sparks do not jump between them, the caps can then be placed on the anodes of the gas-filled rectifiers manually.

Turning on the apparatus once again as described above, the therapeutic circuit can be checked out. Setting the power regulator knob to the second position and using a screwdriver with an insulator handle (inserted through the left-hand opening in the back of the shielded cabinet) the rotor of the variable capacitor can be moved to produce maximum deflection of the needle on the meter. The knob of the power regulator is then set to the 10th position and the meter is again set to the minimum reading. The disk electrode is then very carefully attached (with the voltage switched on) and the power regulator knob is set to the eighth position. A neon lamp is then touched to the electrode wires, and the adjustment knob is rotated to control the therapeutic circuit until the maximum brightness of the lamp is attained. Check to be sure that the maximum brightness of radiation corresponds to the maximum deflection of the needle. If this is not the case, it is necessary to repeat the adjustment of the anode oscillator circuit for the minimum reading of the needle. /257

When the adjustment is complete, the apparatus is disconnected from the line, the interlocks are freed and the shielding and sides of the cabinet are replaced.

PART 6

APPARATUS FOR THERAPY USING A UHF ELECTRICAL FIELD IN A CONSTANT REGIME

§ 1. PORTABLE APPARATUS FOR UHF THERAPY UVCh-62

Portable instruments for UHF therapy are currently in use which have a power of 35-40 watts and were built by the EMA factory in 1950 and subsequent yeats. These instruments are primarily the UVMh-1P and UVCh-2M. A detailed description of them is contained in the second edition of theis book (1960). The production of these devices (UVCh-2M) has been suspended since 1957 because they did not satisfy completely the requirements for shielding against radio interference.

At the same time, the EMA factory invented and began to produce the UVGh-4 apparatus with a power of 80 watts (see Part 2). The size and especially the weight of the apparatus do not permit it to be used as a portable instrument. In connection with this, the VNIIMIO in 1960 developed a new type of portable apparatus for UHF therapy, which delivered a power of 30 watts. Designated the UVCh-62, the apparatus was produced on a mass-production basis by the Union Factory of the EMA. The small size and weight of this apparatus allow it to be used for giving treatments at the patient's bedside, at home or at the clinic. A regime of lower power (15 watts) is available for use with children.

The principle data are as follows: the UVCh-62 apparatus is a generator of electrical oscillations at frequencies of 40, 68mHz ±2%. The apparatus has two stages of output power: the first stage is from 15 ± 3 watts, while the other is 30 ± 5 watts.

The power from the AC line is delivered at a frequency of 50 Hz, 127 or 220 volts. The voltage compensator insures normal operation of the apparatus with deviations in the line voltage from 15% to -25% of the nominal voltage of 127 volts and from 5% to -15% of the nominal voltage of 220 volts.

The maximum power requirement is 200 volt-amperes.

The overall dimensions of the cabinet are 400 × 270 × 200 mm and it weights 10 kgm together with the electrode holders.

The schematic diagram is shown in Fig. 218. The generator with self-excitation consists of a two-stage circuit with a dual beam tetrode GU-19 (represented by V_1 in the circuit). The autogenerator circuit has two parts. The anode section consists of an inductance coil 1, the output capacitances of GU-19, and semivariable capacitor 1. By means of the latter capacitor, the frequency of the autogenerator is set at the factory.

The grid portion of the circuit is formed by induction coil 2 and the input capacitances of tube GU-19. The feedback is achieved through the transient capacitances of the tube, parallel to which are capacitors 2 and 3. Resistors 1 and 2 for automatic bias are connected to the point of zero potential on inductance coil 2. The filament wire of the tube is blocked by capacitor 11 at high frequency, while the screen grid is blocked by capacitor 9. /258

By means of an inductive loop through the circuit formed by inductance coils 3 and 6, the anode circuit of the generator is connected to the therapeutic circuit.

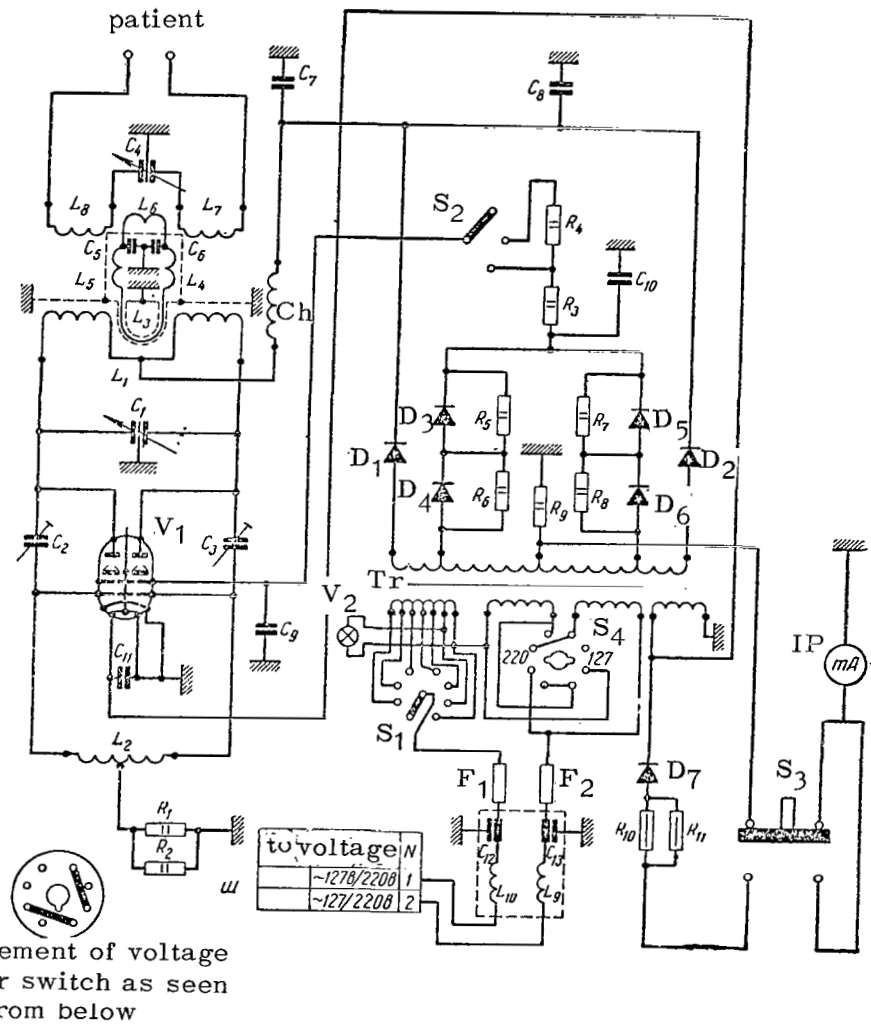


Fig. 218. Schematic Diagram of Portable Apparatus for UHF Therapy, UVCh-62.

Circuits 4 and 5 with capacitors 5 and 6 are intended for filtration of harmonics.

The therapeutic circuit is formed by induction coil 7 and 8 and capacitor 4, which is adjustable. The capacitor serves to set the therapeutic circuit into resonance with the frequency generator when the treatment is being carried out. /259

The anode power of the generator tube comes from the rectifier which is in a full-cycle circuit using germanium rectifiers D_1 and D_2 with filter capacitor 8. The voltage of the anode supply passes from the rectifier output to the center tap of coil 1 in the anode circuit through choke Ch. Capacitor 7 blocks the rectifier at high frequency.

The screen grid of the tube GU-19 is powered by the rectifier which is in a full cycle circuit using semiconductor diodes D_3-D_6 with filter capacitor 10. The circuit of the screen grid contains quenching resistors 3 and 4. Changes in the output power of the apparatus are made by using switch S_2 which controls the quenching resistors.

The rectifiers and filaments of the generator tuves are powered by a power transformer Tr. The primary winding of the transformer divided into sections for connecting it to 127 or 220 volts. The primary winding is fitted with leads which are connected to switch S_1. This switch is used to set the nominal value of the supply voltage for the apparatus. The supply voltage can be checked by means of meter IP. To do this, push button switch V_3 is pressed to connect it to the filament winding of the transformer through semiconductor diode D_7 and quenching resistors 10 and 11. The resistance is selected so that at a nominal value for the supply voltage, the indicator needle will be in the middle of the red zone on the scale. When the button is not depressed, switch V_3 allows the meter IP to be connected in parallel with resistor 9. This means that its reading will be proportional to the sum of the constant components of the anode current and the current of the screen grid of the generator tube.

Incandescent lamp V_2, which indicates that the apparatus is connected to the line, is connected to the filament winding of the transformer.

The supply voltage reaches the primary winding of the transformer through a protective filter consisting of capacitors 12 and 13 and coils 9 and 10. The power circuit contains fuses F_1 and F_2.

Specifications for the Schematic Diagram of the UVCh-62

	Resistors
R -R	MLT-2 10 kΩ±10%
R	MLT-2 6.8 kΩ±10%
R	MLT-2 12 kΩ±10%
R -R	MLT-2 100 kΩ±10%
R	Wire-wound
R -R	MLT-0.25 150 Ω±10%
L -L	Induction coil
L	Connecting coil
L -L	Induction coil
L	Connecting coil
L -L	Induction Coil
V	Vacuum tube GU-19
V	Incandesent lamp MN-14
Tr	Power transformer
Ch	Choke
S ,S	Switch

	Capacitors
C -C	Semivariable air gap capacitors
C	Variable air gap capacitors
C -C	KVKT-20 22 pf±10%
C	KSO-8, 1000V 6800 pf±10%
C	MBGP-2 1000 V 1 μf±10%
C	KSO-5 500 V 68 pf±10%
C	MBGP-2 400 V 2 μf±10%
C	KSO-2 500 V 24 pf±10%
C -C	KBP-R 220 V 0.025 μf±10%
S	Push button switch
S	Switch
IP	Milliammeter M5; 0-100 mA
D -D	Rectifier D-1002
D -D	Semiconductor Diode D7h
F -F	Fuses PM-2
	Line Cord

The design of the apparatus is as follow. The apparatus as shown in Figure 219 is mounted in an aluminum cabinet with a removable front. On the right-hand side of the cabinet are the electrode holders 1. Each electrode holder consists of three Bakelite /260 tubes connected by metal hinges. The top hinge can be rotated around its lengthwise axis. At one end of the electrode holder there is an opening through which the tip of a high frequency wire is passed, with a threaded contact for attaching electrode 2. At the other end of the electrode holder there is a rod which is inserted into a socket attached to the side of the cabinet. Above the socket for the electrode holders there are sockets for plygging in the high-frequency leads.

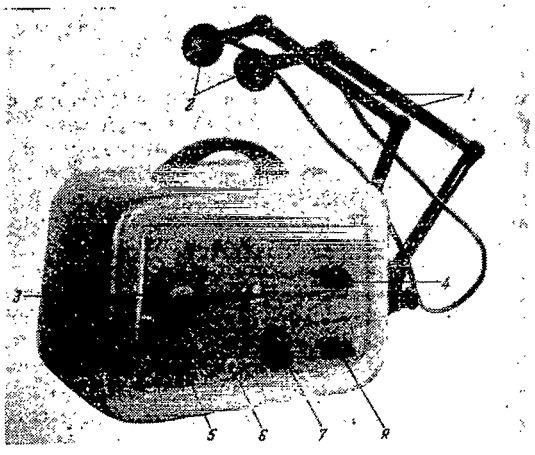


Fig. 219. General View of UVCh-62 Apparatus.

The front of the apparatus serves as a control panel. The following equipment is located on it: at the top are meter 3 and knob 4 for setting the therapeutic value of the circuit, while

at the bottom are knobs 5 for adjusting the power, pushbutton switch 6, pilot light 7, and knob 8 for compensating the line voltage.

Figure 220 shows the apparatus with the cabinet removed. The parts of the circuit are mounted on a chassis which is attached to the front of the cabinet. Below the chassis are the generator section and the therapeutic circuit. A variable capacitor 1 for the therapeutic circuit is located on the left-hand side of the chassis. The knob of the capacitor passes through an opening in the cabinet and can be rotated. Above the capacitor are induction coils 2 for the therapeutic circuit. Between them is a line coil 3. The connecting clamps 4 pass through the metal housing which shields the therapeutic circuit.

The generator tube 5 is mounted on the right-hand side of the chassis. Discs 6 form capacitors with the anode of the tube being connected in parallel with the transient capacitance of the tube. The distance between the discs and the anode can be adjusted when working on the instrument. Inductance coil 7 in the anode circuit is attached to variable capacitor 8. The capacitors is located in a depression on the top of the chassis. Below the chassis are the power transformer, rectifier, coil 9 for the grid circuit, and line filter.

The apparatus is set up as follows to give treatment: First /261
of all, be sure that the voltage switch on the back of the apparatus is set to the proper position. Then check to be sure that the voltage compensator knob and the power selector knob are in the "off"

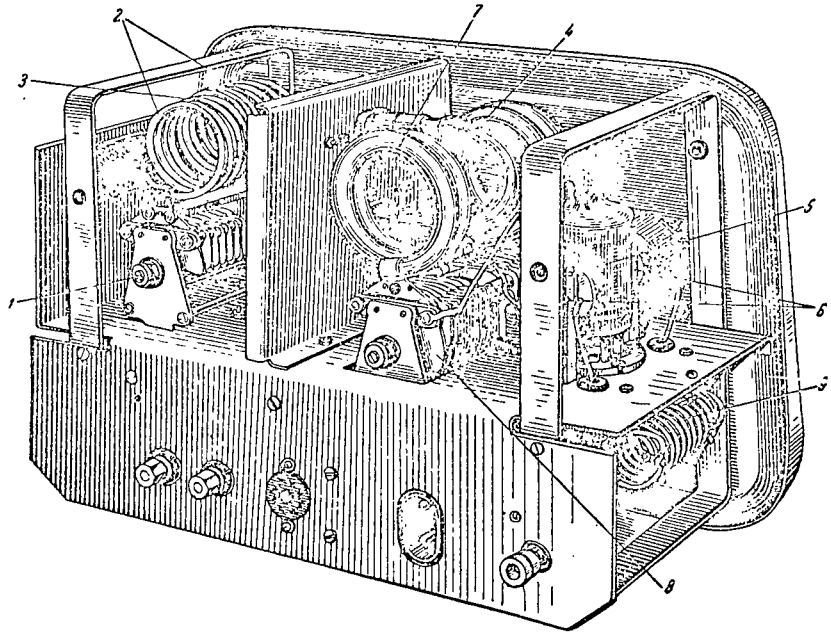


Fig. 220. Location of Parts in the UVCh-62 Apparatus.

position. Then ground the chassis of the apparatus and plug the line cord into the wall.

After placing the electrodes in the desired position with respect to the patient, the compensator knob is set to position 1. This causes the pilot light to go on. While pressing the pushbutton, move the compensator knob until the pointer is within the red area on the scale. After waiting 1-1/2 to 2 minutes, set the power regulating knob either to the 15 watt or 30 watt position. This puts the therapeutic circuit in resonance. The calibration can be checked by means of a neon lamp on the end of a plastic rod. The lamp is first brought close to the end of the electrodes; the adjustment capacitor is then rotated until maximum brightness is obtained. The setting can also be checked on the basis of the maximum deflection of the pointer on the meter (when the pushbutton is not depressed).

When treatment is complete, the power switch must be returned to the "off" position. If there are not be any more treatments, the voltage compensator knob is also returned to the "off" position and the line cord is unplugged from the wall.

§ 2. APPARATUS FOR UHF THERAPY, UVCh-4, OPERATING AT A POWER OF 80 WATTS

This apparatus was devised and produced by the factory of the EMA. The nominal data of this instrument are as follows:

1. generator frequency 39 ± 1 MHz (since April 1, 1963, it has been 40.68 MHz ± 2%).
2. The maximum output power is 80 ± 15 watts. The power can be adjusted in two stages: the first stage is 40 ± 9 watts, and the second stage is 80 ± 15 watts. /262
3. The apparatus operates from an AC line with a frequency of 50 Hz at 127 or 220 volts. The apparatus is provided with a means of compensation for voltage fluctuations from 95 to 133 volts at a nominal value of 127 volts and from 187 to 231 volts at a nominal value of 220 volts. The power consumption with full load is 700 volt-amperes.
4. The overall dimensions of the cabinet of the apparatus are 450 × 300 × 250 mm; it weighs 25 km.

The schematic diagram is shown in Figure 221. The generator operates with a two-stage circuit with self-excitation, using G-811 tubes, (marked 1 and 2 in the curcuit). The anode oscillator circuit consists of inductance coil 2, the output interelectrode-capacitances of the tubes, and adjustable capacitor 3. The grid oscillator circuit consists of induction coil 1 and the output interelectrode capacitances of the tubes. /263 Resistor 1 for automatic bias is connected to the center tap of coil 1. Coil 1 and resistor 1 are located in a separate shielded compartment. The connection between the anode and grid circuits (feedback to the grid) is accomplished only by the transient interelectrode capacitance of the tubes.

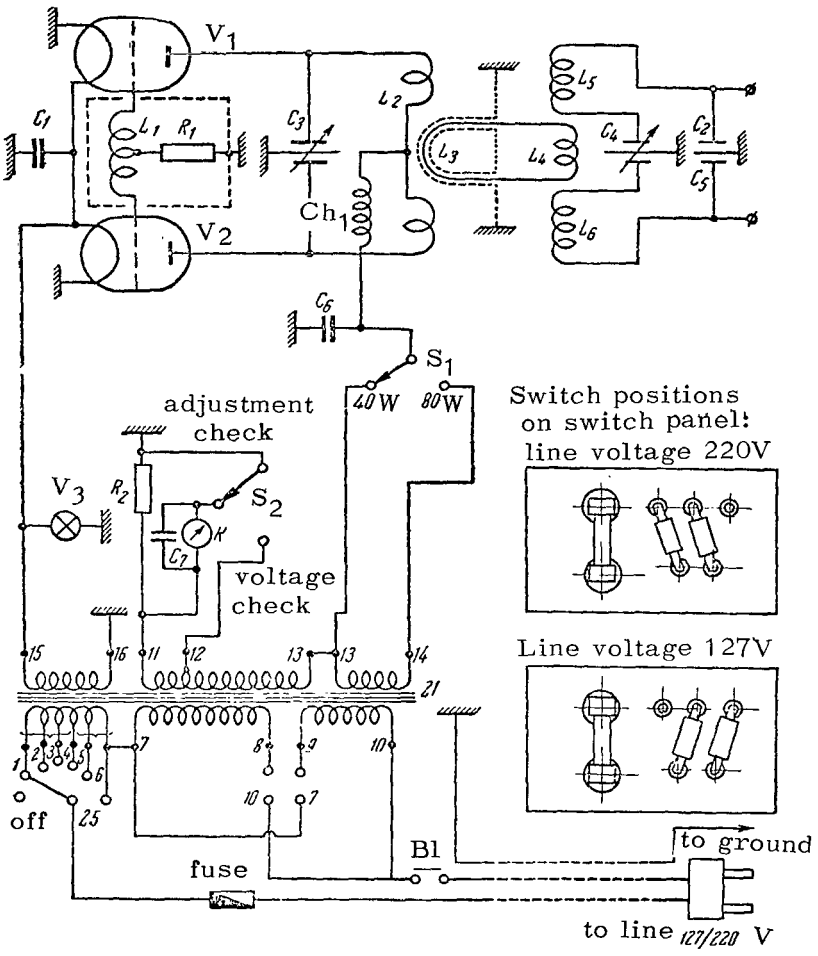


Fig. 221. Schematic Diagram of Apparatus for UHF Therapy, with a Power of 80 Watts (UVCh-4).

The therapeutic circuit consists of induction coils 5 and 6 and capacitors 4 for setting the circuit in resonance, the output terminal, connecting leads, and electrodes for the patient. Capacitors 2 and 5 are connected to the output terminal. They are in the form of two discs, separated from the cabinet of the apparatus by small air gaps which can be adjusted. These capacitors serve as smoothing capacitors which make it possible to adjust the circuit for changes in the gaps beneath the electrodes within considerable limits. The connection between the therapeutic circuit and the electrode circuit is accomplished by means of an intermediate connecting coil, consisting of shielded terminal 3 and coil 4.

The power for the generator is AC from transformer 21. The secondary winding which powers the anode circuit of the generator has two parts (leads 11-13 and 13-14). When working on the first power stage, the voltage cames only from one section, while it comes from both sections when working on the second stage; the two sections are connected in series. A changeover is made by using switch 1. The other end of the secondary winding is grounded through resistor 2. Resistor 2 is also connected to meter K, which indicates the setting; this meter is shunted by capacitor 7. By means of switch 2, the meter can be connected to an additional lead 12 from the secondary winding and then be used to check the voltage supplying the generator.

The filaments of the generator tubes are fed from a separate winding (leads 15 and 16) on the transformer. Pilot light 3 is connected in parallel with this filament.

The primary winding of the transformer is divided into two parts, one for 127 and the other for 220 volts. The voltage compensator winding is connected in series with the primary windings and switch 25 controls these two sections. Fuse F is in the primary circuit of the tranformer, and B1 is the interlack protecting the removable back of the cabinet.

The electrical part of the generator has a number of features which are related to the need to supress radio interference. Of particular importance in this regard are the following: connection of the anode and therapeutic circuits through a connecting coil to the shielded terminal 3, which reduces the capacitor link between the therapeutic and anode circuits, also reducing the passage of even harmonics into the therapeutic circuit; it also ensures maximum symmetry of the two-stage circuit by grounding the center tap of the anode oscillator circuit to a high frequency (capacitor 3); both leads of the filaments of the generator tubes are grounded at high frequency (cqpacitor 1); and the center tap of the capacitance and the output terminal of the therapeutic circuit are also grounded at high frequency (capacitors 4, 2 and 5). There is also increased shielding of individual parts of the generator.

The operating regime of the generator tubes is governed by the

the following nominal values: (a) filament voltage of 6.3 volts; (b) 1350 volts on the anode; (c) the grid current on the two tubes when the apparatus is operated without a load is 38 mA; (d) the anode current for the two tubes is 230 mA.

The voltage on the anode and the anode current must be measured on the basis of the effective value, i.e., by means of an electromagnetic or thermoelectric device. (The anode current can also be measured by using the device on the control panel of the apparatus in the "adjustment position". The total scale of the meter covers 250 mA). /264

The grid current is measured as an average value by a magnetoelectric meter. It should be kept in mind that under the load of the tubes, the grid current decreases.

Specifications for Schematic Diagram of the UVCh-42

V_1-V_2	Vacuum tube G-811
V_3	Miniature incandescent lamps MN-14, E-10; 6.3 V, 0128 A
R_1	Resistor PE-15 1000 Ω±10%
R_2	Resistor PE-15 200 Ω±10%
L_1	Induction coil consisting of 6 turns of MN wire, 2 mm in diameter, silver. Internal diameter of coils equal 26 mm, 5 mm apart.
L_2	Induction coil, 4 turns of copper tubing, 0.5 mm wall thickness, 10 mm in diameter, silver plated; internal diameter of turns, 44 mm.
Ch_1	Choke, 21 turns of PEL wire, 0.93 mm in diameter; internal diameter of turns 18 mm, 1.75 mm apart.
C_1	Capacitor KBG-I, 600 V, 0.01 μf±20%
C_2	Air-gap capacitor 2-3 pf
C_3	Adjustable air-gap capacitor 2 x (15-50) pf
C_4	Adjustable capacitor, air-gap, 2 x (15-300) pf
C_5	Air-gap capacitor 2-3 pf
C_6	Capacitor KVKT-5, 680 pf±20%
C_7	Capacitor KBG-I, 600 V, 0.01 μf±20%
Tr	Power transformer
F_1	High voltage switch, 2-position
F_2	Toggle switch
F	Fuse PV-6 A
RN	Voltage regulator with 7 positions
K	Voltmeter E-421; 0-50 V
B1	Interlock

The design of the apparatus is as follows: the instrument (Fig. 222) is mounted in a metal cabinet with a plastic front which serves as a control panel. On the right side is a socket 1 which supports the electrode holders, as well as sockets for the leads which run to the electrodes. The wires are fitted with terminals at one end for inserting into the socket and on the other end with screw terminals for attaching them to the electrodes. Electrodes 2

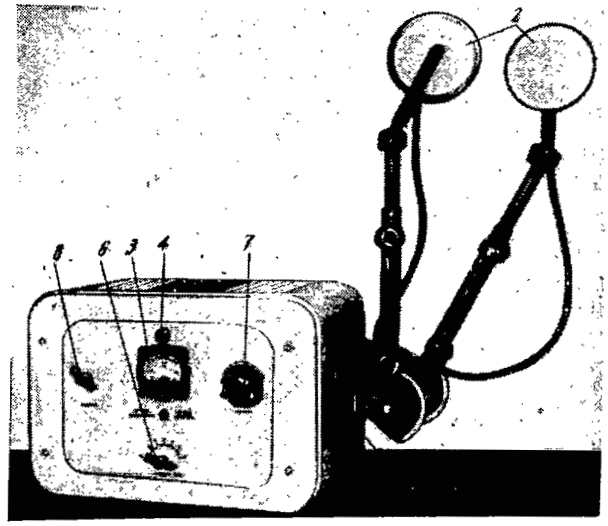


Fig. 222. General View of UVCh-4 Apparatus.

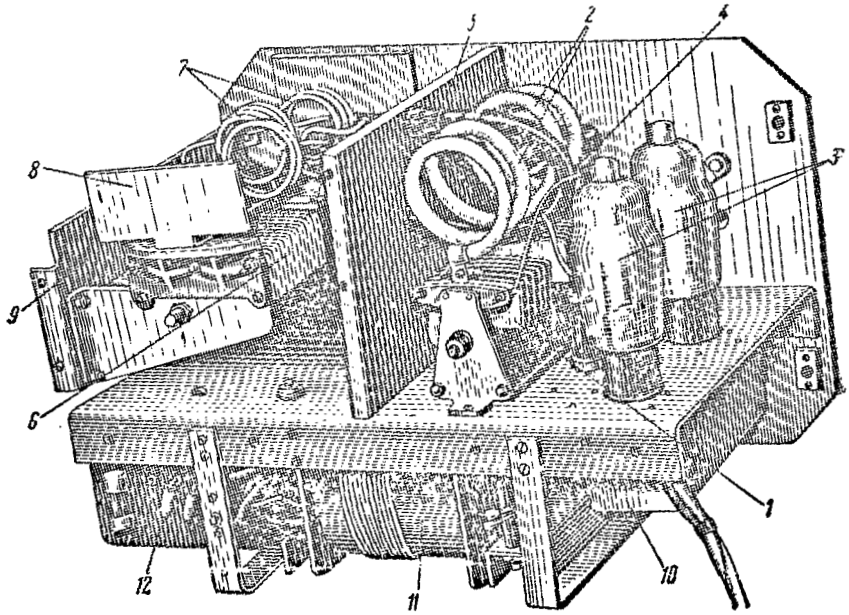


Fig. 223. Arrangement of Parts in the UVCh-4 Apparatus.

consist of metal discs mounted in plastic.

In the middle of the control panel is a meter 3, above which is lens 4 of the pilot light and below it is switch 5 (voltage check-calibration check). Still lower down in the center is knob 6 for the voltage compensator which can also be used to turn on the apparatus. To the right is knob 7 for the capacitor used to adjust the therapeutic circuit, and to the left is knob 8 for the power selector (40 or 80 watts).

The back of the apparatus is removable and is fitted with an electric interlock. After removing the back of the apparatus, the generator, covered on top by a dense shield provided with openings to allow adjustment of the anode circuit capacitor.

Figure 223 shows the apparatus with this shield removed. On the right-hand side are the parts of the anode circuit: capacitor 1 and induction coil 2. Further to the right are the generator /266
tubes 3. Shielded terminal 4 connects the circuit to the therapeutic circuit, which is separated by a vertical shield 5. On the left is capacitor 6 for the therapeutic circuit, connecting terminal 7 and the plates 8 of the corresponding capacitors. On the extreme left of the shield 9 are the sockets for connecting the leads from the electrodes.

Below the table and on the right-hand side, in a shielded compartment 10, are the coils and the resistor for applying the bias to the grid circuit. In the center is power transformer 11 and on the left is panel 12 supporting the contacts for holding the fuse and switching over from 127 to 220 volts and vice versa. There is a special opening in the back of the cabinet opposite this panel. The 3-wire line cord emerges on the right-had side.

The following equipment is supplied with the apparatus:

1. Complete apparatus without vacuum tubes.
2. Electrode holders(2).
3. Wire for connecting electrodes (2).
4. Electrodes, 36, 80 and 113 mm in diameter (2 each).
5. Set of vacuum tubes G-811; 2 each, 2 sets.
6. Fuse, Type PV, 6A (1 installed in the apparatus) (3).
7. Neon lamp, MN-3, on insulated handle (1).
8. Technical description and certificate.

The apparatus is used as follows to administer treatment. First check to be sure that the apparatus is properly set for 127 or 220 volts. The voltage compensator should be in the "off" position, while the instrument switch should be in the "voltage check" position. Then, after being careful to ground the apparatus carefully, the line cord is plugged into the wall.

After placing the electrodes in the required position relative to the patient and running the wires from them to the sockets on

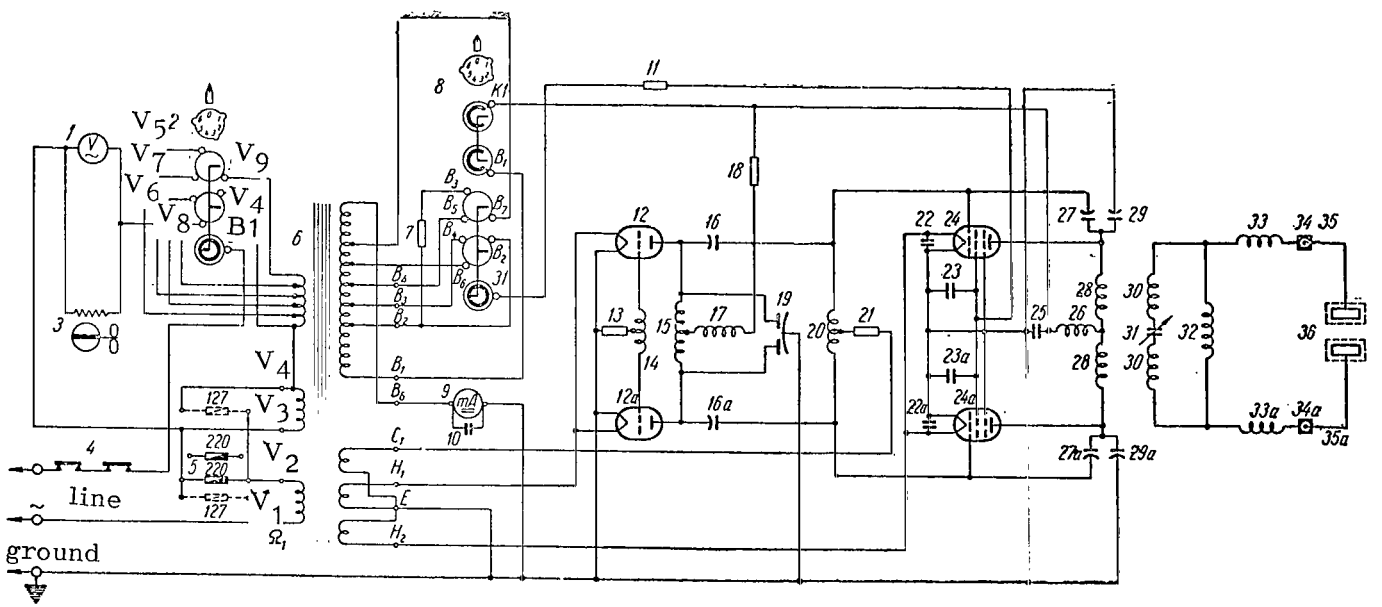


Fig. 224. Schematic Diagram of UVCh-300 Apparatus for UHF Therapy (Power Equal to 300 Watts).

the apparatus, the power selector switch must be turned to the 40 watt or 80 watt position, depending on the type of treatment to be given. Then the current is turned on by rotating the voltage compensator knob; the indicator should point to the red area. Turn the switch to the "setting check". Then, by turning the adjustment capacitor knob, set the therapeutic circuit in resonance so that the maximum deflection of the needle is obtained. The setting can also be checked reliably on the basis of the maximum glow from the indicator lamp on the insulated rod (supplied with the apparatus) by placing it directly against the electrodes.

When the treatment is over, the knob of the voltage compensator should be turned to the "off" position and the line cord pulled from the wall.

According to the data from the factory, the best conditions for achieving full power from the apparatus require operation at distances of 1-1.5 cm between each electrode and the surface being treated.

§ 3. APPARATUS FOR UHF THERAPY, WITH A POWER OF 300 WATTS (UVCh-300)

This apparatus was devised by VNIIMIO and has been mass-produced since 1956.

The principal data are as follows:

The apparatus is a generator of electrical oscillations at a frequency of 39 MHz (wavelength = 7.7 m). The frequency stability is ensured within limits of ± 0.5 MHz; since 1963, the frequency of the generator has been 40.68 MHz ± 2%.

The nominal power in the therapeutic circuit is 300 ± 50 watts. /268 This power is regulated in six stages of about 50 watts each.

The nominal voltage of the power circuit at a frequency of 50 Hz is 127 or 220 volts. The presence of a voltage compensator permits normal operation of the apparatus with the following deviations in the line voltage relative to the nominal value: at 127, +5% to -25%; at 220 volts, from +5% to -15%.

The power consumption with the apparatus operating at full load is 2.3 kVA.

The apparatus has removable electrodes with diameters of 56, 113 and 170 mm.

The overall dimensions of the apparatus with the electrodes raised (see Fig. 225) are 600 x 650 x 1590 mm. The apparatus weights 116 kg.

To ensure suppression of radio interference during operation of the apparatus, it should be operated only in a shielded chamber.

The schematic diagram of the apparatus (Fig 224) contains 4 basic units: (a) master generator, (b) output amplifier, (c) therapeutic circuit, and (d) power supply.

The master generator uses KG-811 tubes (marked 12 and 12a in the circuit) and has a two-stage configuration. To ensure the required frequency stability, the master generator has a power considerably in excess of the power required for driving the output amplifier.

This means that a change in the load on the latter during different procedures has a small effect on the operational effect of this particular generator, thus making it possible to have the required frequency stability.

The anode oscillator of the circuit of the generator consists of coil 15, the interelectrode capacitances of the tube, and the dual adjustable capacitor 19, with the center tap grounded. The oscillator circuit is connected to the control grids of the tubes by coil 14 through feedback. Between the midpoint of the connecting coil and the tube cathodes is the bias resistor 13. The anode circuit of the generator is powered by the external leads V_1 of the secondary winding of the power transformer through the contacts of switch 8, quenching resistor 18, and blocking high frequency choke 17.

The output power amplifier operates with GU-80 tubes (formerly T-800), marked 24 and 24a in the circuit, and is arranged in a two-stage circuit. The output amplifier is connected to the master generator through a pair of coupling capacitors 16 and 16a.

The anode oscillator circuit of the amplifier consists of an inductance coil, 28, the interelectrode capacitances of the tubes, and adjustable capacitors 29 and 29a. The anodes of each tube are linked with the control grid of this tube through neutrodyne capacitors 27 and 27a. A circuit in which neutrodyne capacitors are connected in this manner, differing from conventional ones (as a rule, in the two-stage circuit these capacitors connect the anode of one tube with the control grid of the next tube and vice versa), was due to the necessity of compensating the influence of the high inductance of the lead from the screen grid of the GU-80 tubes.

An independent bias on the control grids of the tubes of the amplifier is provided by a separate winding (leads C_1, E) of the power transformer through resistor 21 and grid coil 20; automatic bias on the grids is also provided by a voltage drop in the grid current across resistor 21. Resistor 21 also serves to limit the grid current during the positive cycle of the independent bias voltage.

The screen grids which are used to regulate the output power /269
of the amplifier are powered from leads B_7 and B_2 of the secondary winding of the power transformer to the contact switch 8 and quenching resistor 11. At high frequency the grids are joined to the tube cathodes through capacitor 23 and 23a. The shielded grids are connected with the cathode tubes and grounded. The filament circuits of the tubes are blocked by capacitors 22 and 22a.

The anode circuit of the amplifier receives its power from the outer lead B_1 of the secondary winding of the coil transformer through the contacts of switch 8 and high-frequency choke 26, blocked by capacitor 25.

The second external lead of the secondary winding of the power transformer is gounded through milliammeter 9, blocked by capacitor 10. This method serves, on the one hand, as an indicator of the setting of the therapeutic circuit in resonance with the frequency of the generator; on the other hand, it provides a rough idea of the output power of the apparatus.

The therapeutic circuit consists of a circuit coil 30, variable capacitor 31, induction coil 32, two matching inductances 33 and 33a, output sockets 34 and 34a, connecting leads 35 and 35a, and electrodes 36.

The power supply consists of the power transformer equipped with the following windings: a primary divided into two parts for connection to 127 or 220 volts, a voltage compensator winding with leads which are connected to switch 2, a secondary winding with a number of intermediate taps for powering the tubes of the master generator and amplifier, a winding for independent bias to the amplifier grids, and two windings for supplying the filament voltage for the tubes in the master generator and amplifier. Voltameter 1 and electric motor 2 with fan are attached to one of the sections of the primary winding of the transformer. The wiring and the power supply include contact 4 for the interlocks protecting the sides of the cabinet and the fuse 5.

The apparatus operates as follows. Apparatus is turned on, (after plugging the line cord into the wall) by turning switch knob 2 of the voltage compensator from zero to the first operating position. This causes the supply voltage fo flow to the primary winding of the power transformer and to the fan motor. From the transformer windin, the voltage passes through the filaments of all the tubes in the apparatus. An independent bias is also applied to the control grids of the amplifier tubes. When the knob is moved from the first to the other operating positions, the operating voltages are increased in nominal value, corresponding to the position of the needle on the red part of the scale of the voltmeter, mounted on the control panel of the apparatus.

In order to obtain the high voltage which powers the anode

circuit of the master generator and amplifier, it is necessary to move power selector knob 8 from the zero to the first operating position. This allows the power to reach the master generator and the high-frequency voltage to reach the control grids of the tubes of the amplifier, so that the entire circuit is in operating condition. The minimum voltage is then applied to the screen grids in the tubes of the amplifier and the amplifier operates at low power.

As the switch knob is moved to other positions, the voltage applied to the screen grids of the tubes in the amplifier is increased, so that the power delivered by the amplifier in the therapeutic circuit also increases.

Specifications for Schematic Diagram of UVCh-30 Apparatus /270

1	Voltmeter E-30 0-150 V
2	7-position switch
3	Fan VN 127 V, 50 Hz
4	Interlock
5	Fuse PN-10 10 A
6	Transformer
7	Resistor VS-5 1500 Ω±10%
8	7-position switch
9	Milliammeter MZ40 0-500 mA
10	Capacitor KSO-5 33 μμf±20%
11	Resistor PE-75 1000 Ω±10%
12,12a	Vacuum tubes G-811
13	Resistor VS-2 5100 Ω±20%
14	Feedback coil
15	Inductance coil
16,16a	Air-gap capacitor
17	Choke PEL wire 0.51 mm 31 turns
18	Resistor PE-50 15,000 Ω±10%
19	Dual adjustable capacitor
20	Choke PEL wire, 0.51 mm 2 x 32 turns
21	Resistor VS-5 5100 Ω±20%
22,22a	Capacitor KSO-5 3300 μμf±20%
23,23a	Capacitor KSO-7 3300 μμf±20%
24,24a	Vacuum tube GU-80
25	Capacitor KG-6 470 μμf±20%
26	Choke Nichrome wire, 0.5 mm, 32 turns
27,27a	Air-gap capacitor
28	Inductance coil
29,29a	Air-gap capacitor
30	Inductance coil
31	Variable capacitor
32	Inductance coil
33,33a	Inductance coil
34,34a	Output terminals
35,35a	Wires to connect electrodes (feeders)
36,36a	Electrodes

The general appearance of the instrument is as follows. The apparatus is mounted in a metal cabinet provided with handles on the sides and rollers for convenience in moving. The front, side and bottom of the cabinet can be removed.

A general view of the apparatus is shown in Figure 225. The back of the cabinet (see Fig. 226) is provided with electrode holders 1. The electrode holders are movable hinged rods whose upper ends hold electrodes 2, and whose lower ends are mounted in rotating mounts 5. These mounts are fastened by bolts to the top (nonremovable) part of the cabinet. Between the mounts for the electrode holders is electric motor 7, with a fan whose blades are located inside the cabinet.

Below each of the electrode holders is a socket 6 into which the wires 4 from the electrodes are plugged. The line cord emerges from the side of the apparatus.

The top of the apparatus is flat and serves as a control panel (Fig. 225). At the top of the panel are the meters: at the left is voltmeter 3 for voltage compensation and on the right is milliammeter 4 which is connected to the cathode circuit of the amplifier; below these are 3 regulating knobs: at the left is knob 5 for the voltage compensator switch, in the center is knob 6 for capacitor 31 in the therapeutic circuit, and on the right hand is knob 7 for the power selector. The knobs for the voltage compensator and power selector. The knobs for the voltage compensator and power selector switches rotate clockwise only as far as the extreme operating position (they must be returned to the "off" position by turning them counterclockwise), and they are mechanically arranged so that the compensator knob can be moved out of the "off" position only when the switch is in the off position.

The arrangement of the parts inside the cabinet is shown in /271
Figures 226 and 227. In the lower part of the cabinet, near the back (Fig. 226) and located in a special shielded compartment, is the master generator: tube 9, between them the coil of the anode circuit, and in front of that, the intermediate capacitor 10. To the right of the generator unit is panel 8 with fuses. The panel has 4 sets of contacts; the two pairs at the top are for fuses used when the machine is being operated on 220 volts, while the two at the bottom are for use with 127 volts.

On the front (see Fig. 227) is the power transformer tube; on both sides of its are switches; the one on the left is 7 for the voltage compensator and the one on the right is 8 for the power regulator. The knobs of these switches protrude through the top and emerge on the control panel. Above the transformer is resistor 6 for biasing the amplifier. The top compartment contains the parts of the output stage: tubes 3 and behind them the anode coil and blocking choke, while on the sides are neutrodyne capacitors 4 and adjustable capacitors 5. On the panel itself are the circuit coils,

inductance coils, and matching inductances for the therapeutic circuit.

At the back of the upper part of the apparatus is fan 10, and next to it the knobs for switches 7 and 8.

The supports for the metal part of the cabinet are fitted with bottons 1 for the interlocks protecting the removable panels.

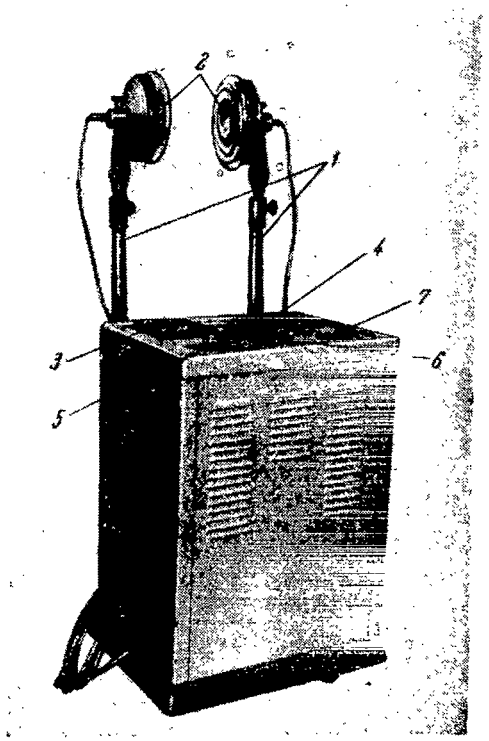


Fig. 225. General View of the UVCh-300 Apparatus.

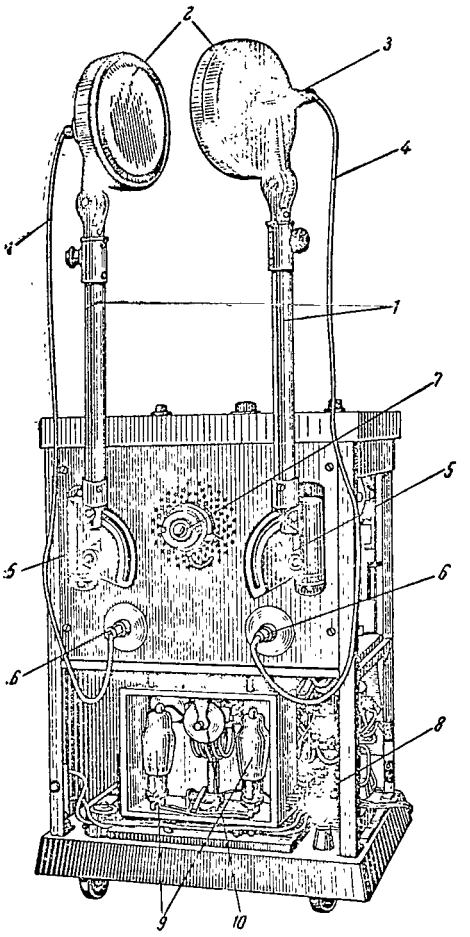


Fig. 226. Arrangement of Parts Inside the UVCh-300 Apparatus (Rear Panel Removed).

The following equipment is supplied with the unit:

1. Disc electrodes with glass holders, 56, 113 and 170 mm in diameter (2 each),
2. Connecting wires for electrodes (2),
3. Electrode Holders (2),
4. Vacuum tubes GU-80 (4)
5. Vacuum tubes G-811 (4)
6. Fuses, 10 and 20 A (2 each),
7. Technical Description, Instructions and Certificate for Apparatus.

The apparatus is set up as follows for administering treatment./272 Before beginning treatment, electrodes of the proper diameter must be selected and the proper gap set between the metal disc and the glass holder. This is done by turning the threaded knob 3 (Fig. 226) which moves the electrode disc the required distance; the knob must then be tightened again. The electrodes are mounted on the electrode holders with the aid of set-screws and are connected to the socket by the connecting leads.

The electrode holders are then mounted in the required position relative to the patient. The patient must assume a comfortable, relaxed position in which he can remain until treatment is complete, since movement of the patient between the electrodes may cause a distrubance in the established regime of the procedure.

After checking to see that the voltage compensator knob and the power selector are in the zero position, the apparatus can be plugged into the wall. The voltage compensator knob is then set to the first operating position. This should cause the fan to begin operating with an audible sound and the filaments of the amplifier tubes should be visible through the grating on the panel; the voltmeter needle should also move away from the zero position. The compensating knob is then moved to other positions until the voltmeter needle is on the red portion of the scale.

The power selector switch is then turned from zero to the first operating position and the capacitor of therapeutic circuit is rotated until the circuit is in resonance, as shown by a maximum deflection of the needle on the milliammeter. If the deflection of the pointer is in significant and it is difficult to achieve a maximum, the switch is moved up to the second or third position and the adjustment is made again.

If the procedure is to be carried out at low power, it is easier to adjust the therapeutic circuit on the basis of the maximum brightness of the neon lamp, which is placed near the electrodes, instead of the deflection of the milliammeter needle.

After adjusting the therapeutic circuit and placing it in resonance, the knob of the power switch is turned to the last position to set the power at which the procedure is to be carried

out according to the doctor's instructions, on the basis of the patient's sensations and the reading of the milliammeter.

It is likely that the apparatus will have to be checked and the setting of the therapeutic circuit adjusted back to resonance one or two times during the treatment. /27

If the patient complains of a sensation of local heat, the power must be reduced by turning the power selector knob one notch clockwise. When treatment is complete, the power selector switch and then the voltage compansator knob are returned to the zero position. If treatments are given in a series, the compensator knob need not be used between treatments.

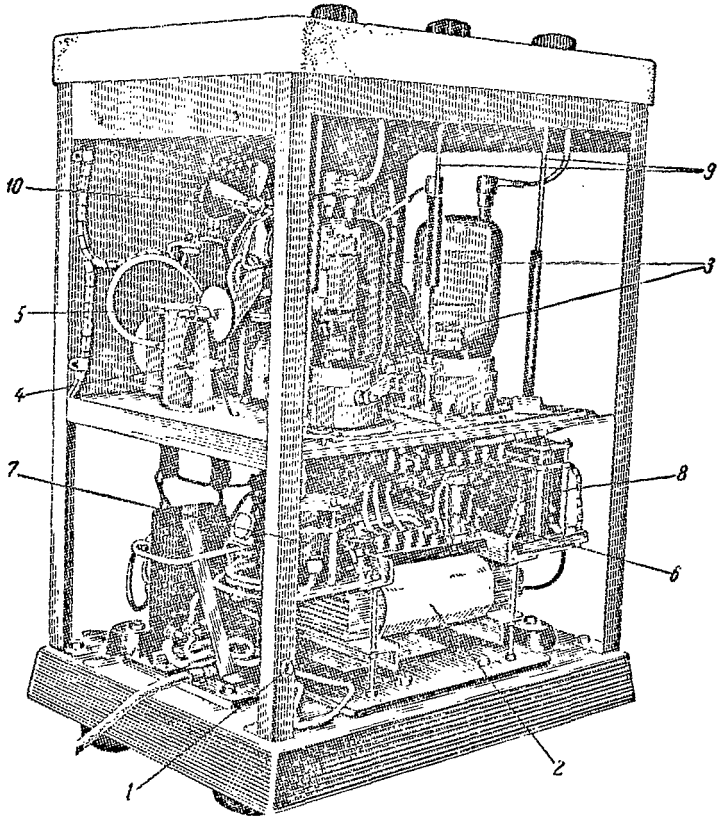


Fig. 227. Arrangement of parts in the UVCh-300 (View With Front Panel Removed).

When all treatments are complete, the knob of the compensator must be returned to the zero position and the plug removed from the wall socket.

The following are some remarks regarding the use of the apparatus. When setting up the apparatus after receiving it from the factory, it is necessary to remove the front panel of the cabinet and the cover of the shielded compartment, to install the G-811 tubes in their sockets, and to fasten the contacts to the anode terminals of the tubes; the machine should then be checked for correct operation of the fuses on 220 volts (the apparatus is shipped this way from the palnt) or (if necessary) the fuses can be replaced by those for 127 volts. The shield and panel are then replaced. The front panel is then removed, the tube-holder clamps are removed, the GU-80 tubes are plugged into their sockets according /274 to their markings, ("right" and "left"), the ring contacts are slipped onto the top terminals of the tubes (onto the right-hand terminal of the left-hand tube and onto the left-hand terminal of the right-hand tube; these contacts are connected to the anode circuit; the other leads are contacts which are connected to the cabinet of the apparatus). The panel is then replaced and the electrode holders are attached to the back panel. The power cord is then plugged in: the ends L and L_1 run to the terminals and the end E is attached to the grounding clamp. The apparatus is now ready for use.

According to the instructions from the factory for ensuring normal operation of the apparatus, it is necessary to observe the following precautions when using it:

(a) After constant operation of the apparatus for 1 1/2-2 hours at the fifth or sixth stage of output power, the apparatus should be disconnected for at least an hour to avoid overheating of the windings in the power transformer.

(b) To avoid overheating of the tubes, the apparatus should not be left in operation without a load and the high voltage turned on, especially in the case of small distances between the electrodes and with the therapeutic circuit in resonance.

(c) When operating the apparatus, the "adjust" knob of the therapeutic circuit capacitor must always be in a position corresponding to the maximum deflection of the milliammeter (adjustment to resonance); the use of this knob to adjust the output power is not allowed.

(d) The apparatus should be kept clean by wiping it with a moistened cloth on the outside. Dust must be removed from inside the cabinet very carefully to avoid damaging the parts; in no case should dust be wiped off the parts of the apparatus and contacts by using a cloth.

(e) The adjustment and care of the apparatus must be entrusted

only to qualified personnel, and under no circumstances should the adjustable capacitors be moved, since this will throw the device out of adjustment.

(f) At certain intervals (every 200-250 hours of operation) the fan should be oiled. A few drops of machine oil can be added with an ordinary oil can into special openings provided for this purpose at both ends of the fan motor. Since one of the openings is located inside the cabinet, it is necessary to remove the front panel of the apparatus for oiling; if this is not sufficient, one of the side panels should also be removed, after first removing the handle from the cabinet.

(g) The apparatus should be stored in a dry, warm location.

The following are some remarks concerning the placement of tubes. The G-811 tube can be removed without making any further changes to the apparatus.

When replacing a fualty GU-80 tube, it is possible for the anode circuit of the power amplifier to be affected so that the operating regime of the tubes will not be optimum. Therefore, when replacing the GU-80 tube, the anode circuit of the power amplifier should be checked for resonance. For this purpose, the apparatus is turned on and the line cord disconnected from the wall; the front and side panels of the apparatus must then be removed and the set screws on adjustable capacitors 5 (see Fig. 227) loosened, after which the front panel can be removed; the gounding of the apparatus should be checked as well. The large electrodes are connected to the apparatus and the distance between them is set to 20-30 cm.

The adjustment is carried out in the following order: (a) /275
The adjustment knob on the control panel is turned so that the blades of the rotor in capacitor 31 are separated, thus changing the capacitance and affecting the entire therapeutic circuit; (b) The plug is then inserted in the socket on the apparatus, and the instrument turned on by means of the voltage compensator knob; the power selector knob is then moved to the fourth position; (c) The kandle of the movable disc in capacitor 5 is then rotated by using a screwdriver with an insulated handle and the reading of the milliammeter on the control panel is observed. The minimum current is set so that the gaps between the blades of the capacitors will be approximately the same; (d) After adjustment is complete, the power selector knob is returned to the zero position and the set-screws for the capacitor knobs are replaced carefully in order not to disturb the setting. (It is not recommended that the knobs of the other adjustable capacitors be moved). Then, after turning off the apparatus, the panels can be replaced and bolted back on.

During adjustment, it is necessary to observe all safety rules very carefully in view of the fact that some parts of the apparatus are at high voltage during operation.

PART 7

THERAPEUTIC APPARATUS USING A PULSED UHF ELECTRIC FIELD

The first therapeutic apparatus using pulsed UHF electric field was devised by VNIIMIO. A great many of these instruments were produced by the experimental laboratory of the Institute under the designation UVChI-1 (see the second edition of this book, 1960). In 1960, this apparatus was modernized and produced by the experimental laboratory of the VNIIMIO in small numbers with the designation "Impul's-2".

The "Impul's-2" is intended for pulsed UHF therapy, i.e., for therapy using a UHF electric field in a pulsed regime. The basic technical data are as follows: the apparatus is a generator of electric oscillations at a frequency of 39 $\pm$ 1 MHz with pulse modulation. The shape of the modulated pulses is close to rectangular, the duration of the pulses is 2 and 8 microsec, and the duty factor is 1000 (the pulse frequencies are 500 and 125 Hz, respectively).

The maximum output power per pulse is 15 $\pm$ 2 kW. The output power is adjustable in seven stages.

The nominal line voltage is 127 or 220 V. The voltage compensator can be used to ensure normal operation of the apparatus with the following deviations in line voltage from the nominal value: at 127 V, from +5% to -25%; at 220 V, from +5% to -15%.

The power consumption of the apparatus when operating at full load is 600 volt-amperes.

The apparatus has removable capacitor electrodes mounted in plastic; they are 56, 113, and 170 mm in diameter.

The overall dimensions of the apparatus are 1010 x 580 x 470 mm; it weighs 70 kg.

To shield the apparatus against radiation or radio interference, it must be operated only in a shielded chamber.

The block diagram of the apparatus is shown in Figure 228. The apparatus consists of the following seven basic units: (a) generator of short pulses, (b) submodulator, (c) modulator, (d) generator of UHF oscillations, (e) therapeutic circuit, (f) power supply, (g) stage for automatic adjustment of the therapeutic circuit. /276

The schematic diagram of the apparatus is shown in Figure 229. The generator for UHF oscillations uses GI-17 flash tubes (V_7 and V_8) in a two-stage circuit with self-excitation. The oscillator system of the generator consists of cathode and grid oscil-

lator sections. The tube anodes are grounded. The cathode oscillator section is connected to induction coils 17, capacitors 44-45, and the output capacitances of the tubes. The grid oscillator circuit consists of inductance coil 13 and the transient capacitances of the tubes. In order to increase the feedback, capacitors 42 and 43 are connected in parallel with the input capacitances of the tubes.

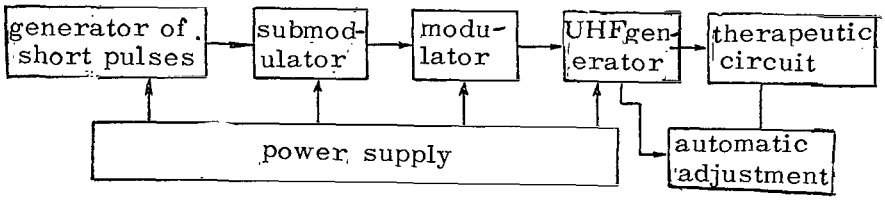


Fig. 228. Block Diagram of Apparatus for Pulsed UHF Therapy, "Impul's-2".

The control grids of the tubes receive automatic bias from resistor 36, which is connected in series with choke 14 and shunted by capacitor 46. The filaments of the generator tubes are powered from a separate winding on transformer 6 through the center tap of coil 17. The filament circuit of the tubes contains blocking chokes 15-16 and capacitors 40-41.

The power for the anode circuit of the tubes comes from a series circuit through the center tap of inductance coil 17.

The therapeutic circuit is connected inductively with the oscillator circuit of the generator, and consists of coils 18-19, adjustable capacitor 59, matching inductance coil 20, and electrodes E.

The modulator which produces the anode modulation of the generator oscillations of basic frequency consists of the following: (a) a generator of short pulses, consisting in turn of a blocking generator and a cathode repeater; (b) a submodulator; (c) the modulator itself, or a switching system.

The blocking generator uses a 6N7 tube (marked V_4 in the circuit), and both halves of the latter are connected in parallel. The anode and grid circuits of the tubes contain the windings of the pulse transformer Tr_8. The grid circuit also contains capacitor 20 and toggle switch T_1 with leak resistors 28, 31, and 29, 30. Toggle switch T_1, located on the control panel, can be set to one of two

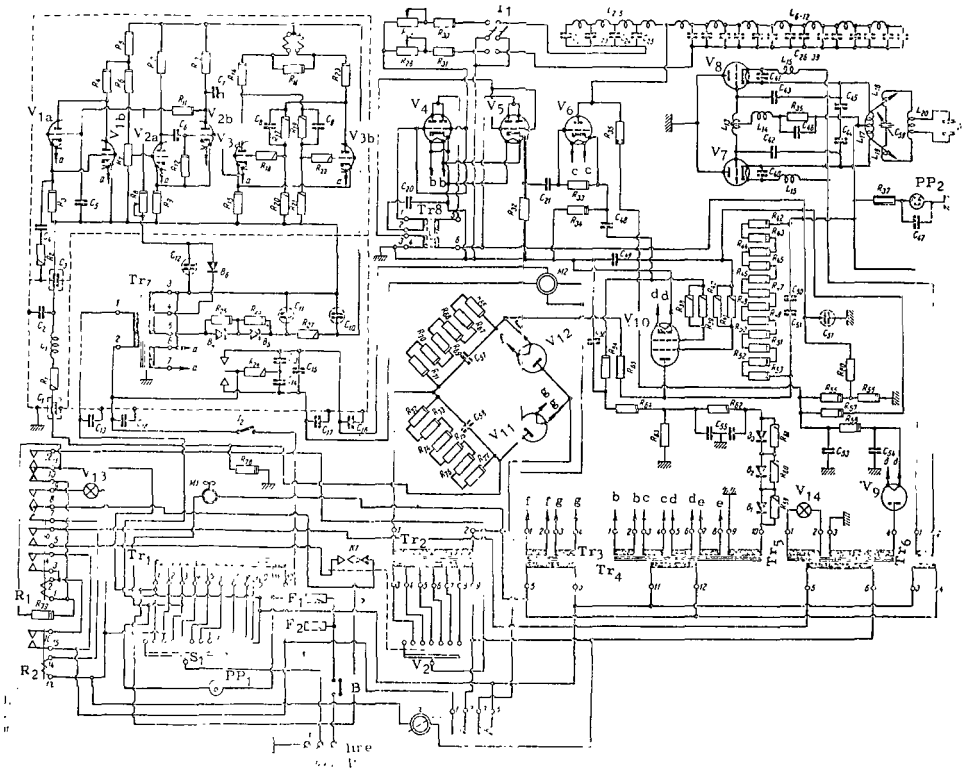


Fig. 229. Schematic Diagram of "Impul's-2" Apparatus.

possible pulse frequencies. Variable resistors 28 and 29 are intended for adjusting the pulse frequency of the blocking generator at the factory.

The third output winding of the pulse transformer is connected to the tube grid of the cathode repeater.

The cathode repeater operates with a 6N7 tube (marked V_5 in the circuit), both halves of which are connected in parallel. The positive pulse for triggering the submodulator is formed across resistor 32, which is connected in the cathode circuit of the tube.

The submodulator consists of thyratron TGI1-35/3 (marked V_6 in the circuit), which produces a discharge of one or both pulse lines (coils 2-5 and capacitors 22-25, or coils 6-12 and capacitors 26-39). /277

In the interval between pulses, the thyratron is not operating, and the pulse circuit is charged from the power supply through resistor 35. The trigger pulse from the cathode repeater reaches the grid of the thyratron through capacitor 21, so that the thyratron ignites and the pulse passes through it. The pulse circuit, as it discharges, generates a pulse across resistor 34 (connected in the cathode circuit of the thyratron) in a form which is very close to rectangular. This pulse then passes through capacitor 48 to the grid of the switching tube in the modulator. The pulse duration is determined by the parameters of the pulse circuit. The circuit consisting of coils 2-5 and capacitors 22-25 produces a pulse lasting 2 microsec; the circuit consisting of coils 6-12 and capacitors 26-39 produces a pulse lasting 8 microsec. The circuits can be switched simultaneously with the pulse frequency by means of toggle switch T_1.

The modulator operates in a regime with partial discharge of storage capacitors 50-51. The pulsed modulator tetrode GMI-83 (V_{10} in the circuit) is used as a switching tube.

During the intervals between pulses, the tube is closed by a high negative bias, placed on the control grid by a separate rectifier. When the tube is closed, the storage capacitors 50-51, which are connected in series, discharge to supply the anode circuit of the high-frequency generator. The capacitors are charged by a separate high-voltage rectifier, operating in a dual circuit, through resistors 65 and 37 and through a meter (milliammeter PP_2). In the interval between pulses, the storage capacitors which are connected to the control and screen grids of the switching tubes are also charged (capacitor 49 through resistor 57, and capacitor 56 through resistor 54). The circuit for these grids contains antiparasitic resistors 38-39 and 40-41 to prevent stimulation of oscillation processes.

As the brief pulse from the submodulator passes through capac-

itor 48 to the control grids of the switching tubes, the tubes open and storage capacitors 50-51 discharge partially through the switching tubes and the anode circuit of the high-frequency generator tubes.

The design of the therapeutic circuit is based on milliammeter PP_2. In fact, this apparatus measures the average charging current of the storage capacitor supplying the generator. However, the average charging current of the capacitors is equal to the average discharge current, and the latter is the average anode current of the generator) without taking into account resistor 37, which shunts the generator). Therefore, the apparatus measures the average anode current in both generator tubes, making it possible to adjust the therapeutic cirucit.

The power supply consists of the following special parts: (a) autotransformer 1 with switch S_1 for voltage compensation of the supply voltage; (b) transformer 2 which supplies the high-voltage rectifier included in the dual circuit with high-voltage kenotrons V_1-0.02/20 (marked V_{11} and V_{12} in the circuit) and capacitors 57-58.

The primary winding of transformer 2 is divided into sections for stepwise regulation of the voltage supply to the anodes of the generator tubes, and therefore for regulation of the output power of the generator.

(c) There is a transformer 3 which supplies the filament circuit of the high-voltage kenotrons 11 and 12 in the dual circuit. /278

(d) Transformer 4 supplies the filament circuit of the generator tubes for the brief impulses, the submodulator, modulator, and high-voltage kneotron 9. The transformer also has a winding for supplying the rectifier for the bias circuit to the switching tube, consisting of semiconductor diodes (marked S_1-S_3 in the circuit).

(e) Transformer 5 powers the rectifier, operating in a half-wave circuit) and a filter composed of capacitors 53-54 and resistor 58. The rectifier supplies the anode circuit of the submodulator, the circuit for the screen grid of the switching tubes (through quenching resistor 57) and the anode circuits of the tubes in the generator for the brief pulses, as well as the cathode repeater (the voltage divider made up of resistors 56-55).

(f) Transformer 6 powers the filaments of the generator tubes.

In addition, the power supply contains electric motor M_1 for the fan, which is used to cool the generator tubes; the relay block which ensures the time delay required for the thyratron to warm up, the switching and generator tubes, voltmeter PP_1 for measuring the value of the voltage in the power supply, automatic timer Ch

which disconnects the high voltage when the time for treatment set on the dial has elapsed, as well as the unit for automatic setting of the therapeutic circuit in resonance.

The relay block consists of thermal time-delay relay R_2 with a bimetallic strip whose contacts close to supply voltage to the windings of the auxiliary electromagnetic relay R_1. The contact relay R_1 makes the necessary charges in the circuit. Blocking is provided by means of microswitch K_1, mechanically linked to the power selector T_2, which controls the thermal relay so that it can operate only when the power switch knob S_2 is set to zero.

The circuit for primary transformer 1 contains contacts B of the interlock for the removable panels of the cabinet, as well as the interlock (F_1 and F_2) which are also used for connecting the primary windings of the transformer to either 127 or 220 volts.

The unit for automatic adjustment of the therapeutic circuit consists of (a) reversible electric motor M_2 connected by a flexible coupling to the rotor of variable capacitor 59 in the therapeutic circuit; (b) polarized relay R_3, which controls the direction of rotation of the motor; (c) a unit containing vacuum-tube relays (tubes V_1-V_3), which controls the polarized relay, and (d) transformer 7 with a selenium rectifier for powering the entire unit.

The output of this unit is connected to resistor 78 in the high-frequency rectifier circuit, which supplies the anodes of the generator tubes. The power for the primary winding of transformer 8 comes from autotransformer 1 through toggle switch E_2.

Automatic adjustment of the therapeutic circuit is accomplished by turning the rotor of variable capacitor 59 by means of the flexible coupling connected to electric motor M_2. During the adjustment process, the capacitor rotor is subjected to an oscillating motion of low amplitude around a position corresponding to the setting of the therapeutic circuit in resonance with the frequency generator.

The change in the direction of rotation of the electric motor is produced by an abrupt change in the anode current of the generator tubes, produced by "frequency skipping" of the generator. A sharp drop in the anode current in the generator tubes causes a negative pulse to appear on the grid of tube V_{1b}; following amplification, the pulse activates an electronic relay with one fixed position, made up of triodes L_{2a} and L_{2b}. /279

The positive pulse from the anode of triode L_{2b} passes through capacitor 7 to the electronic relay with two fixed positions and then to triodes V_{3a} and V_{3b}. This pulse flips the relay from one fixed position to the other. This involves operation of polarized relay R_4, whose contact is connected to the wires supplying the

windings of electric motor M_2, changing the direction of its rotation. Hence, each change in the anode current of the generator, involving a change in its frequency, causes a change in the direction of the rotation of electric motor M_2.

During the operation of the apparatus, the rotor of the motor, as well as the rotor of the capacitor in the therapeutic circuit, undergo oscillations of small amplitude around a middle position. For example, if the movement of an object between the electrodes disturbs the setting of the therapeutic circuit, the system will automatically adjust to compensate for it: the rotor of the motor will rotate in the required direction, stop in the new position when the adjustment is complete, and then oscillate around a new midpoint.

The unit for automatic adjustment can be disconnected by means of toggle switch T_2, so that the adjustment of the therapeutic circuit can be made manually as usual.

The apparatus operates as follows. When turning on the apparatus, S_1 for the voltage compensator must be set to the first working position so that the supply voltage reaches the primary windings of transformers Tr_3, Tr_4, and Tr_5, the voltmeter, and the fan motor. The filament voltage is also transmitted to all the tubes, the bias voltage is applied to the control grid of the switching tube (closing it), and voltage is also applied to the coil in the thermal relay to ensure the proper delay. By moving the knob of switch S_1 to subsequent operating positions, the normal supply voltage is set according to the voltmeter reading.

After 3-4 min, thermal relay R_2 operates, connecting the circuit to auxiliary relay R_1. When relay R_1 operates, the contacts of the thermal relay are blocked and the voltage to its winding is cut off; the supply voltage then goes to the wiper of power switch S_2 and the free contact of microswitch S_1 is connected to the primary winding of transformer 5. At the same time, pilot light V_{15} lights up to signal the fact that the high voltage can now be turned on. When knob S_2 is switched from zero to the first position, microswitch K_1 operates and (if the timer is turned on) the supply voltage passes to the primary windings of transformers 2 and 5. The high voltage is then able to power the anode circuits of all the tubes in the system. Pilot light 14 then lights up. When the high voltage comes on, storage capacitors 50-51 and capacitors 22-25 or 26-29 of the pulse circuit of the submodulator are charged; at the same time, the blocking generator starts up and brief pulses are transmitted through the cathode repeater to the submodulator. Each of the brief pulses ignites the thyratron and a brief pulse passes through the latter to form a positive pulse of a certain duration on the control grid of the switching tube. The switching tube opens and the charged capacitors discharge through it and through the anode circuit of the generator tubes. This is called self-excitation of the generator. The gener-

ation period continues for a period of time which is determined by the duration of the modulator pulse. /280

When the pulse is complete, the switching tube closes, generation stops, and there is a pause between the pulses, during which the capacitors 50-51 and the modulator line charge once again, etc. Pulsed modulation of the generator proceeds in this fashion.

Specifications for Schematic Diagram of "Impul's-2"

Resistors

1	MLT-0.5 5100 Ω±10%	30	MLT-1 51 kΩ±10%
2	MLT-0.5 12 kΩ±10%	31	MLT-1 0.3 MΩ±10%
3	MLT-0.5 7.5 MΩ±10%	32	MLT-1 10 kΩ±10%
4	MLT-1 15 kΩ±10%	33	MLT-1 33 kΩ±10%
5	MLT-1 0.22 MΩ±10%	34	VS-5 510 Ω±10%
6	MLT-1 0.24 MΩ±10%	35	VS-5 10 kΩ±10%
7	SP-1 220	36	VS-2 1200 Ω±10%
8	SP-1 1000	37	PEV-50 10 kΩ±10%
9	MLT-1 11 kΩ±10%	38-41	VS-0.5 27 Ω±10%
10	MLT-1 0.51 MΩ±10%	42-53	MLT-2 2.2 MΩ±5%
11	MLT-1 0.68 MΩ±10%	54	MLT-1 2 kΩ±10%
12	MLT-1 2.0 MΩ±10%	55	MLT-2 150 kΩ±10%
13	MLT-1 20 kΩ±10%	56	VS-5 430 kΩ±10%
14	MLT-1 27 kΩ±10%	57	VS-5 270 kΩ±5%
15	MLT-1 10 kΩ±10%	58	VS-2 10 kΩ±10%
16	MLT-1 43 kΩ±10%	59-61	MLT-0.5 150 kΩ±5%
17	MLT-0.5 1.5 MΩ±10%	62	MLT-1 2200 Ω±10%
18	MLT-0.5 51 kΩ±10%	63	VS-5 33 kΩ ±10%
19	MLT-0.5 1.5 MΩ±10%	64	MLT-1 5100 Ω±10%
20-21	MLT-0.5 0.39 MΩ±5%	65	PEV-25 10 kΩ±10%
22	MLT-0.5 51 kΩ ±10%	66-77	MLT-2 2.2 MΩ±5%
23	MLT-1 27 kΩ±10%	78	VS-5 4700 Ω±10%
24	MLT-0.5 510 Ω±10%	79	VS-5 3600 Ω±10%
25-26	MLT-0.5 0.15 MΩ±5%	80	MLT-1 6800 Ω±10%
27	MLT-0.5 1 kΩ±10%		
28-29	SP-P 47		

Capacitors

1	KBP-R 500 V; 0.025 μf±10%	22-39	POV 10kV, 390 nf
2	MBGP 200 V	40-41	KSO-5 500 V; 2700 nf
3	KBP-R 500 V; 0.025 μf±10%	42-43	KVKV-11 47 nf±20%
4	KBG-MN 200 V; 0.025μf±10%	44-45	KVKV-10 56 nf±20%
5	KSO-2 500 V; 0.25 μf±10%	46	KVKT-12 56 nf±20%
6	KBGI 200 V; 0.1 μf±10%	47	KBG-I 200 V; 0.1 μf
7	KSO-2 500 V; 100 nf±10%	48-49	KBG-MN 1500 V; 1 μf±10%
8-9	KBGI 600 V;0.0047μf±5%	50-51	KBG-P 4 kV 0.5 μf±10%
10-11	KE-2 400 V; 20 μf	52	KE-2 450 V; 10μf
12	KE-2 150 V; 20 μf	53-54	KBG-P 3 kV; 1 μf±10%
13-14	KBG-I 400 V;0.05μf±10%	55	KBG-MN 400 V; 1 μf
15	KBG-MN 200 V; 1 μf±10%	56	KBG-MN 1000 V; 1 μf
16-19	KBG-I 400 V; 0.05μf±10%	57-58	KBG-P 0.25 μf
20-21	KSO-8 2500 V; 3900 nf	59	Air-gap capacitor

Inductances

L_1, L_{14}, L_{15-16} Choke

L_{2-5}, L_{6-12}, L_{13}, L_{17}, L_{18-19}, L_{20} Inductance coil

Vacuum Tubes

V_{1a}, V_{1b}	6N1P	V_7-V_8	GI-17
V_{2a}, V_{2b}	6N1P	V_9	V1-0.02/20
V_{3a}, V_{3b}	6N1P	V_{10}	GMN-83
V_4-V_5	6N7S	V_{11}-V_{12}	V1-0.02/20
V_6	TGI1-35/3		

/281

Other Parts

B_1	Semiconductor diode	K_1	Microswitch
V_{13}-V_{14}	Incandescent lamps	PP_1	Voltmeter
M_1	Ventilator	PP_2	Milliammeter
M_2	Electric motor	F_1	Fuse
Ch	Timer	F_2	Fuse
Tr_1-Tr_2	Transformers	S_1	11-position switch
Tr_8	Pulse transformer	S_2	8-position switch
R_1	Electromagnetic relay	T_1-T_2	Toggle switch
R_2	Thermal relay	B	Interlock
R_3	Polarized relay	E	Electrodes

The design of the apparatus is as follows: a general view of the apparatus is shown in Figure 230. The instrument is mounted in a metal cabinet with removable front and back panels. On the right-hand side are the supports for the electrode holders. The top of the cabinet is sloped and serves as a control panel. The control panel has the following parts on it: at the top left is voltmeter 1, to the right of it is milliammeter 2. On a line with these meters are the lenses of the pilot lights: at the left is 3 (green) indicating that the time-delay relay is operating, at right is 4 (red) which indicates that the high voltage is switched on. Between the pilot lights is the time knob 5. In the middle of the panel are two toggle switches: the one at the left (6) is for setting the pulse duration (2 and 8 microseconds), and the one on the right (7) indicates that the automatic adjustment is turned on.

On the lower part of the panel are three control knobs: the one at the left (8) is for switching the voltage compensator, the one in the middle (9) is for adjusting the therapeutic capacitor, and (10) at the right is for adjusting the power.

Figure 231 shows the location of the parts and components within the cabinet with the front panel removed, while Figure 232 shows them with the back panel removed.

The cabinet contains a power supply at the bottom, the gener-

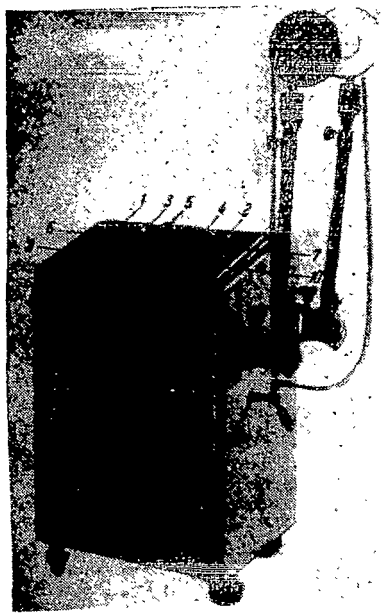


Fig. 230. Overall View of "Impul's-2" Apparatus.

ator and modulator in the middle, and at the top (below the control panel) the automatic adjustment mechanism, the relay block, and other controls.

At the left front (Fig. 231) is the modulator unit 1 with switching tube 2. On the right (on a separate chassis) is a high-frequency generator. Generator tubes 3, with their filament leads, are at the top, as are the parts of the generator circuit, inductance coil 4 of the cathode circuit with coils 14 in the therapeutic circuit, and choke 5 for the filament circuit of the tubes. Lead 6 for the grids of the /282 generator tubes and grid coil 7 are located below the chassis. Ventilator 8 is located near the pilot light.

Below the control panel is variable capacitor 9 for the therapeutic circuit. The control of the capacitor passes through an opening in the control panel and is fitted with a knob.

The lower part of the cabinet contains the following parts: at the left is autotransformer 10, in the center is transformer 11 for the high-voltage rectifier used to power the generator of brief pulses and the submodulator, along with storage capacitors 12 for the modulator; on the right-hand side is high-voltage transformer 13 which powers the doubling circuit.

On the back (Fig. 232), the unit for automatic adjustment of the therapeutic circuit 1 is located at the top; in the middle at the left is the generator unit, and on the right is modulator unit 9. In the bottom of the cabinet on the left-hand side is transformer 2 for the filaments of the generator tubes 10, with resistor 3 mounted above it in the discharge circuit for the storage capacitors. Transformer 4 for the filaments of the high-voltage kenotrons in the doubling circuit is also located here. The kenotrons 5 are mounted on the panel above the transformer.

On the right-hand side is transformer 6 for the filaments of the modulator tubes, with kenotrons 7 for the rectifier supplying the short-pulse generator mounted above it; it also powers the submodulator. The filter capacitor 8 for this rectifier is located next to it.

The apparatus is used as follows for administering treatment.

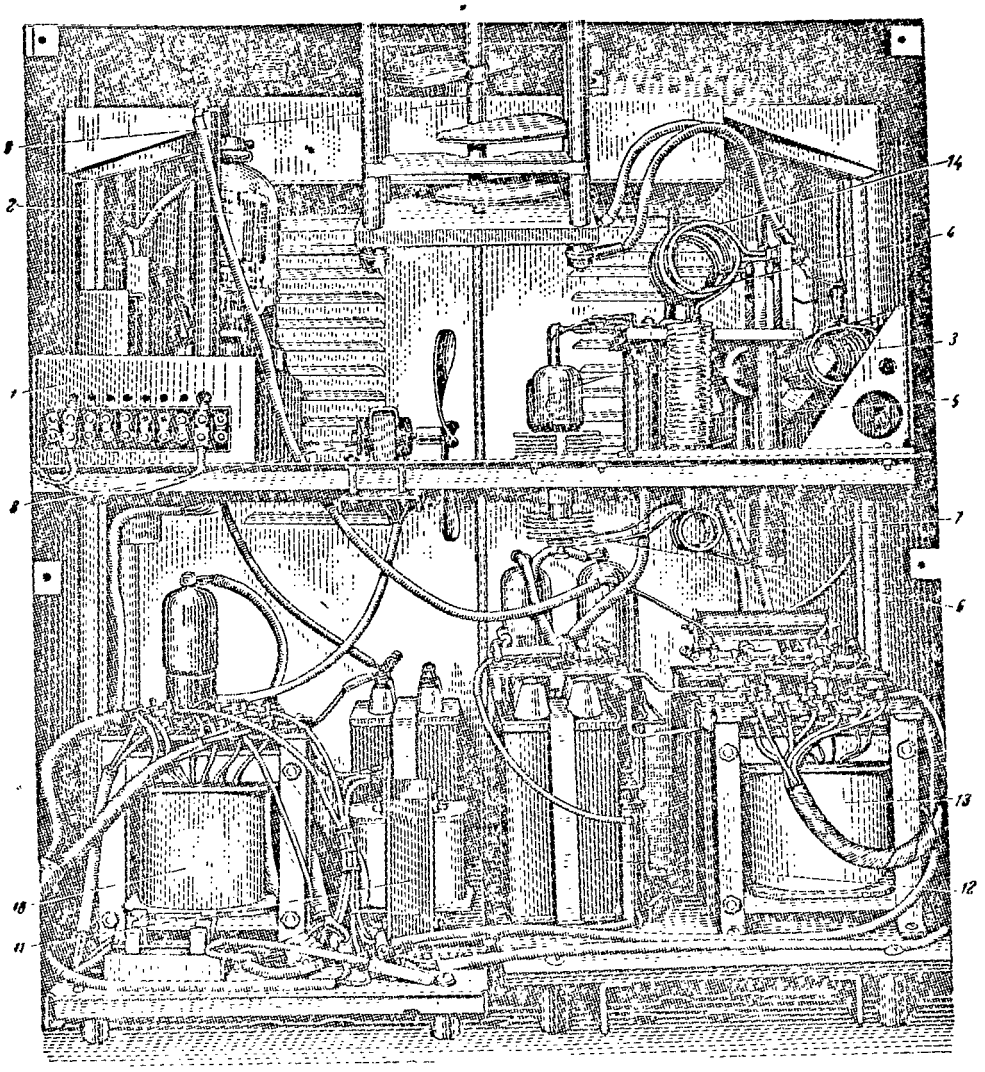


Fig. 231. Location of Parts in the "Impul's-2" Apparatus (View With Front Panel Removed).

The general rules for using the "Impul's-2" apparatus are similar to those given above for the use of the UVCh-300. After fastening the electrodes to the electrode holders (choosing those of the proper diameter) and turning the screws in the centers of the electrodes to set the proper gap, the electrodes are placed in the required position relative to the patient.

The apparatus can then be switched on. Check to be sure that the voltage compensator knob and power regulator are set to the zero position. The toggle swtich is set to the desired pulse duration of 2 or 8 microseconds. The switch for the automatic adjust-

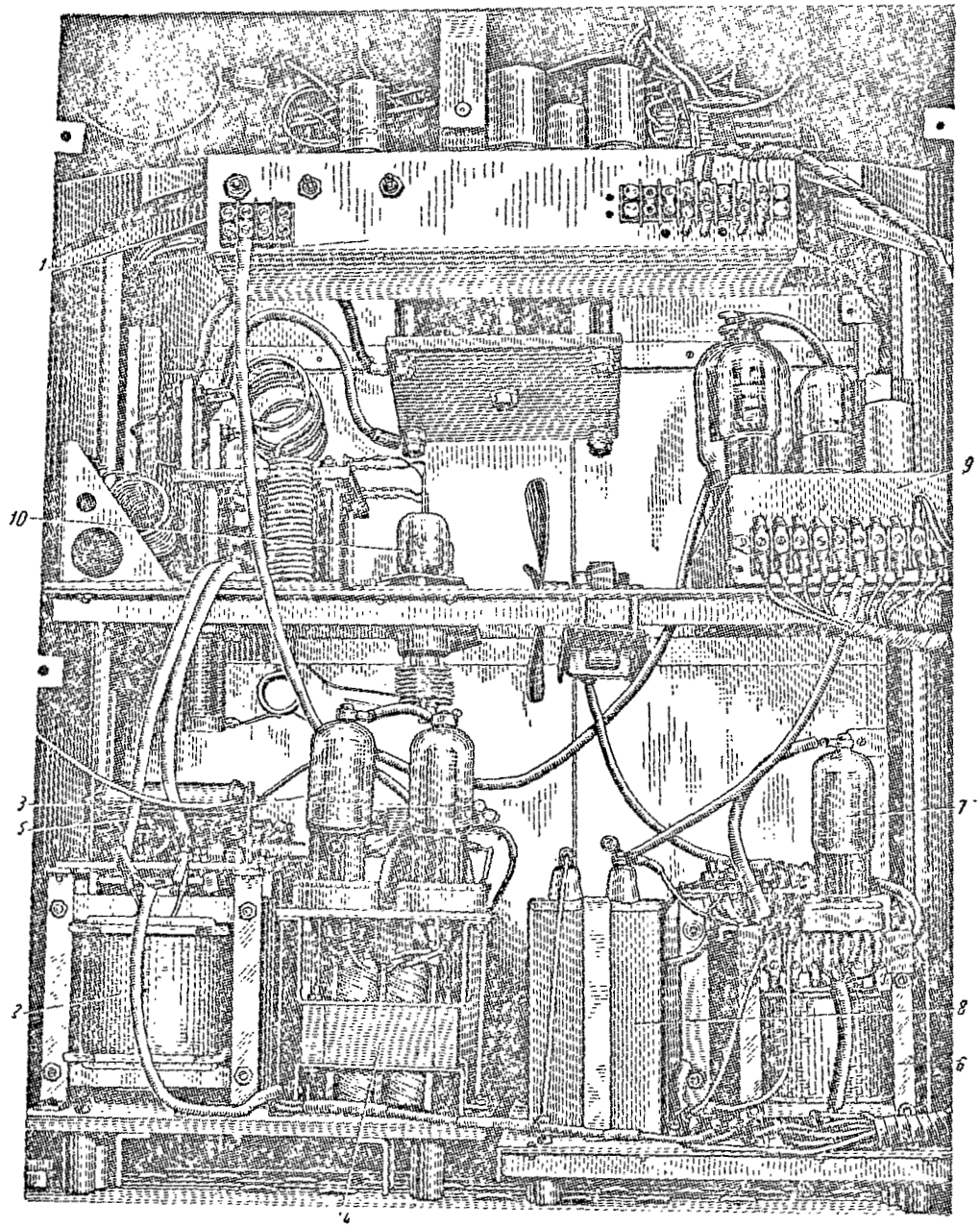


Fig. 232. Location of Parts in the "Impul's-2" Apparatus (View With Back Panel Removed).

ment is thrown to the "off" position. The voltage compensator knob is set to the first and then to the other positions until the voltmeter needle is on the red zone. Wait for the time-delay relay to operate (3-4 min). When the relay operates, the white pilot light on the left side will go on. Set the timer to the position corresponding to the required duration of treatment (the apparatus will not operate unless the timer is set). /284

Then move the power adjustment knob to the first position. This will cause the red pilot light on the right to go on and the while one on the left to go out. Set the therapeutic circuit resonance by watching for the maximum deflection of the milliammeter needle or by using a neon lamp held against the electrodes. After adjustment, the power regulator knob is set to the desired position for treatment.

If it is desired to use the automatic adjustment, the automatic adjustment toggle switch is set to the "on" position. After a short period of time required for the tubes in the electronic relay to warm up, the adjustment knob and capacitor rotor will begin to oscillate around a midpoint to adjust the setting automatically. The adjustment knob should not be touched at this time.

When the time set on the timer has elapsed, the high voltage which powers the modulator and generator is automatically disconnected and the red pilot light goes out.

The power selector switch must be returned to the zero position (so that the while pilot light lights up once again), and the toggle switch controlling automatic adjustment must be thrown to the "off" position.

The next treatment can then be carried out. If this is the last treatment, the voltage compensator knob is reset to the zero position and the plug is disconnected from the wall. The comments regarding the use of the "Impul's-2" generally agree with those for the UVCh-300 as given above.

PART 8

APPARATUS FOR MICROWAVE THERAPY

§ 1. MAGNETRON GENERATOR

Obtaining electromagnetic oscillations of very high frequency /285
by means of vacuum tubes of conventional design is difficult for two significant reasons. In the first place, the interelectrode capacitances and inductances of the tube leads may exceed the magnitude of the capacitance and inductance required for obtaining VHF oscillations; in the second place, the time required for the electrons to travel between the cathode and grid is the same as the period of the oscillations or even exceeds it, so that the entire operating process of the generator as discussed previously is disturbed.

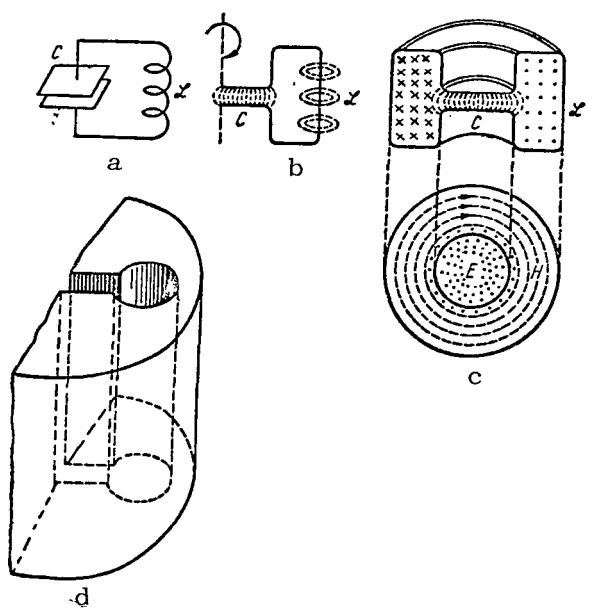


Fig. 233. Diagram of Conversion from an Oscillator Circuit to a Volume Resonator.

VHF oscillations can be obtained by means of special generator tubes called magnetrons. A magnetron combines the functions of a vacuum tube and the oscillator circuit of a conventional generator. The oscillator system of a magnetron is an empty space located at its anode, called the volume resonator.

Volume resonators or endovibrators are oscillator systems which incorporate closed empty metal containers. The transition from a closed oscillator circuit to a volume resonator can be explained by the following diagram. In Figure 233, a, we see a conventional oscillator circuit containing inductance coil L and capacitor C. Figure 233, b shows an oscillator circuit consisting of one winding, whose central portion forms a half turn-inductance while the flat ends (which are parallel to one another) form the capacitance of the circuit. The figure shows the lines of force of the electrical and magnetic fields in the circuit. Figure 233, b shows a volume resonator whose shape can be con- /286
sidered the result of the rotation of the turn of wire in Figure 233, b around a vertical axis. In Figure 233, b, we can also see the lines of force of the electric and magnetic fields. The

electric field is concentrated between the middle parts of the resonator which are parallel and close to one another; a magnetic field is formed between the flattened ends of the resonator. The volume resonator in Figure 233, c has the shape of a chamber with thin walls. However, a volume resonator can also be a recess (with certain limits to its surface) of a suitable shape, formed for example in liquid metal. Such a resonator, cylindrical in shape, is shown in Figure 233, d.

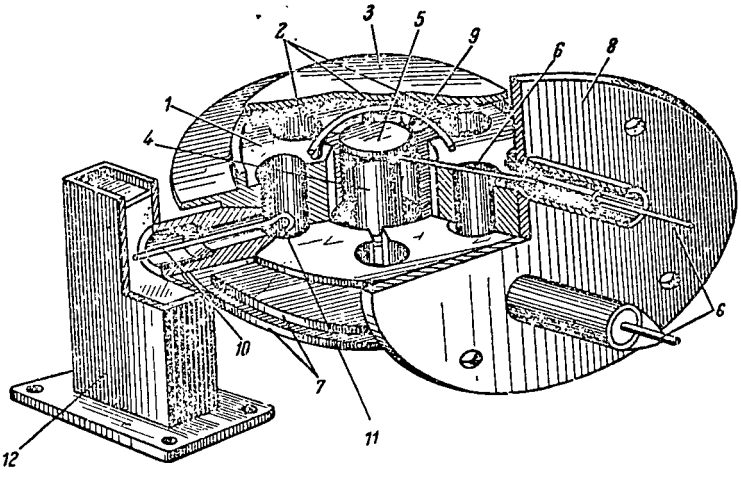


Figure 234. Diagram Showing Construction of a Magnetron.

The magnetron is a vacuum chamber with two electrodes, a cathode and anode, to which constant voltages are applied. The chamber is located in a constant magnetic field, perpendicular to the electric field acting between the anode and the cathode. To produce this effect, the magnetron is mounted between the poles of a magnet so that the lines of force of the magnetic field are parallel to the cathode. The electrodes which are located in the space between the anode and the cathode are subjected to the simultaneous influence of the electric and magnetic fields.

The design of a magnetron is represented schematically in Figure 234. The magnetron is a squat cylindrical vacuum chamber most of which is occupied by anode 1, which has the shape of a massive copper cylinder with resonators 2 arranged radially. The anode segments thus formed are corrected by current-carrying leads 9. The chamber is sealed on the sides by hermetic covers (in Figure 234, the top cover 3 is only shown partially). In the center of the chamber is a heater cathode 4 in the shape of a cylinder, which acts as a powerful source of electrons. Disks 5 are soldered to the ends of the cathode, to suppress electron scattering to the sides. Holders 6, which act as the filament leads, run to the disks; they are insulated from the chamber. Between the cathode and the anode of the magnetron there is a constant supply

voltage of considerable magnitude. The positive pole of the power source is connected to the filament leads, while the positive pole of the power supply is grounded; the anode of the magnetron is also grounded. /287

To transmit the oscillations of the energy from the magnetron to the load in one of the resonators, there is a high-frequency lead, one end of which has the shape of a loop 11, located in a plane perpendicular to the axis of the resonator, while the other is rod-shaped and located in the bottom of waveguide 12 (see below).

The anode is fitted with metal radiators 7 to improve cooling. The magnetron is held in place by flange 8. The magnetron is located with the end surfaces between the poles of a sufficiently strong permanent magnet.

To explain the principle of operation of a magnetron, let us first examine the nature of the motion of electrons in it under the influence of the internal sources of constant electrical and constant magnetic fields, with an anode in the form of a flattened cylinder (without resonators). The lines of force of the electric field are located radially, parallel to the plane of the paper in the direction from anode to cathode (Fig. 235). The lines of force of the magnetic field are arranged perpendicular to the plane of the paper (for example, in the direction toward the observer; these lines are represented by dots in the plane of the paper). Under the influence of these fields, the electrons which emerge from cathode K will move in space along an epicycloid trajectory whose configuration depends on the relationship between the electric and magnetic fields. Figure 235 is a schematic representation of the paths of the electrons with some constant direction of the electric field and with a gradual increase in the magnetic field from small values (curve 1) to rather high ones (curve 4). In the latter case, the electrons may return to the cathode if they do not reach the anode. At a certain ratio between the intensities of the electric and magnetic fields, an electron flux may be formed in the magnetron and it will then move at a certain rate along (at a tangent to) the surface of the anode.

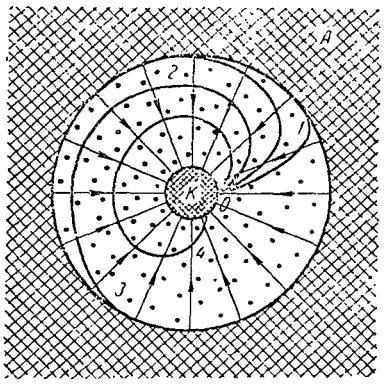


Fig. 235. Diagram of the Trajectory of Electrons in the Static Regime of a Magnetron.

Let us now consider the diagram of the electric and magnetic fields which are found in an operating magnetron (Fig. 236, left half). The resonators of an excited magnetron produce alternating

high-frequency electromagnetic fields. The lines of force E of the electrical component of this field are concentrated primarily between the walls of the sections of the resonator. The lines of force H of the magnetic component of this field are concentrated primarily in the regions of the resonator which are located along their axes (i.e., perpendicular to the plane of Fig. 236, a) and are trapped between adjacent resonators, as shown in Figures 236, a and b. The magnetic currents corresponding to these lines form a inductive link between the resonators. The equivalent diagram of the oscillator circuit formed by the resonators is shown in the right-hand half of Figure 236,a. In Figure 236, a, on the left-hand side, we can also see the lines of force E_o of a constant electric field, directed radially, as well as the capacitances /288
C_o corresponding to them in the right-hand side of the picture.

Hence, when the electric oscillations arise in the resonators, the electrons will be under the influence of as many as three fields: (a) a constant magnetic field directed radially

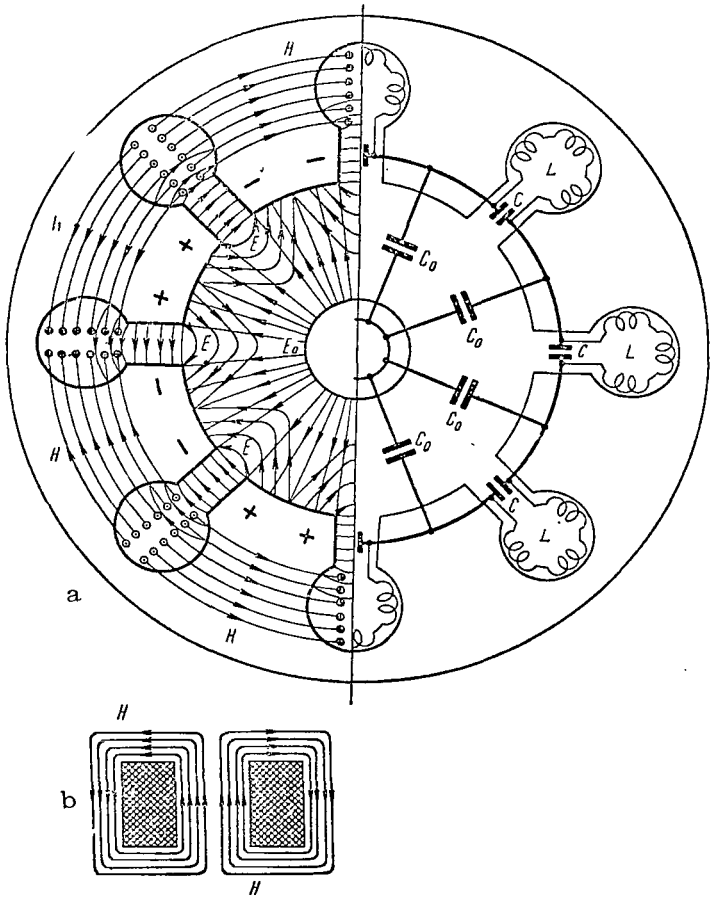


Fig. 236. Diagram of Electrical and Magnetic Fields in a Magnetron.

between the anode and the cathode, and (c) an alternating electric field formed in the resonators and in the space between the cathode and the anode, having the direction shown in Figure 236.

Let us examine the action of the alternating electric field of the resonators from the standpoint of the electron travelling between them. To do this, let us divide the force vector E into two components at each point in the field: these will be the radial component E_r and the tangential component E_t.

The radial component E_r will be combined with a constant electric field E_o and will reinforce it on one side of the resonator and weaken it on the other. In the places where the field is intensified, the motion of the electrons will be accelerated; in those places where the field is weakened, they will be slowed down. As we can easily see from Figure 237, the electrons located below resonator I will approach one another (condense); those /289
below resonator II will move away from one another (scatter). As a result, the trajectories of the electrons travel along radially directed paths (Fig. 238), the number of which corresponds to the number of pairs of resonators in the anode circuit. As a whole, the electron flux will resemble the spokes of a wheel rotating around the cathode.

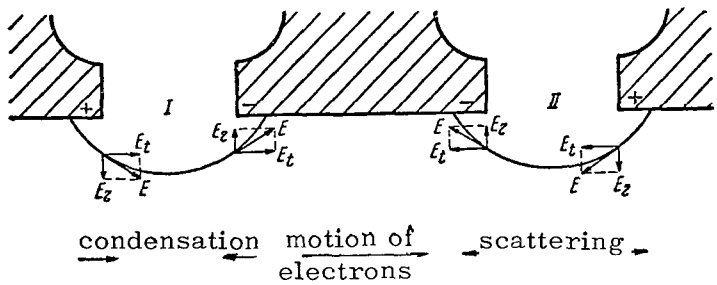


Fig. 237. Diagram of Interaction between Constant and Hihg-Frequency Electric Fields in a Magnetron.

The constant electric and constant magnetic fields in the magnetron are adjusted so that the rotation of the electron flux will take place synchronously with the frequency of the oscillations which are produced in the resonators. In this case, the locations where the electron flux is increased ("spokes" of the electron cloud) will coincide with the electric fields of the resonators in which the tangential component E_t is directed, so that a braking effect is produced on the electrons. The braking effect of the field means that the electrons which possess kinetic energy as a result of the interaction with the basic field will give it up in an interaction with the resonator field. This energy is converted into electric oscillations in the resonators and can be used accordingly.

Self-excitation of a magnetron takes place even when there is only a very weak yet constant electromagnetic field in the resonators; it is formed, for example, in connection with the thermal motion of the electrons. This means that as the electrons move they begin to group together and an electron flux begins to produce a potential differerence on the segments of the anode (Fig. 239), thus reinforcing the field of the resonators and creating saturation of the operational regime.

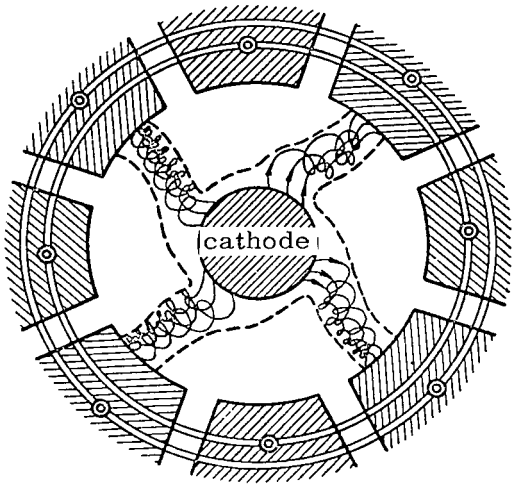


Fig. 238. Diagram of Electron Flux in an Excited Magnetron.

The anode segments are connected together by ring-shaped connectors 9; one of the resonators contains a loop of wire 10 (see Fig. 234) /290 soldered at one end to the anode and connected to a coaxial cable. The loop serves as a terminal in contact with the magnetic field of the resonator. Oscillations are induced in it which pass through the coaxial cable to the load.

It is possible to show the analogy between the operation of a magnetron and the vacuum-tube generator with an oscillator circuit discussed previously (Fig. 240). The circuits of these generators are arranged in the diagram so that analogous elements are located above one another. In the vacuum-tube generator, the oscillations in the circuit are reinforced by oscillations in the anode circuit which are synchronous with them and arise as a result of feedback from the connection to the tube grid. In the magnetron, the oscillations in the resonators are supported by alternating potentials which are synchronous with the rotating irregularities in density of the electron flux, formed under the influence of the electrical component of the field of the resonators (feedback in the magnetron).

In the vacuum-tube generator, the electrons which constitute the anode flux obtain energy from a power source through interaction with a constant electric field in the tube and liberate it by means of interaction with the alternating electric field of a capacitor in the circuit. In the magnetron, the electrons also receive energy from a power supply as in the process of interaction with a constant electric field and liberate it by interaction with the electric component of the resonator field.

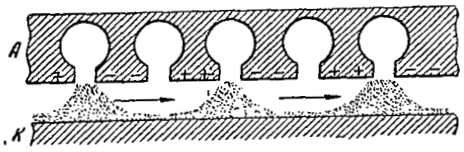


Fig. 239. Diagram of Production of Oscillations in Resonators.

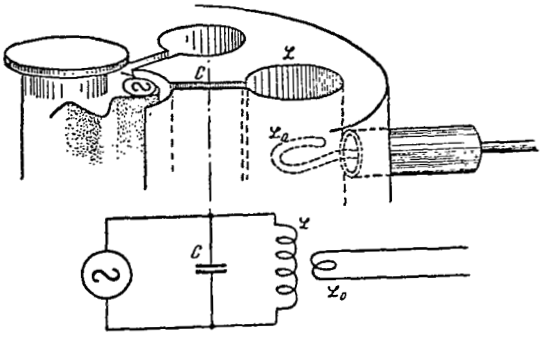


Fig. 240. Comparison of the Circuits of the Magnetron and a Vacuum-Tube Generator.

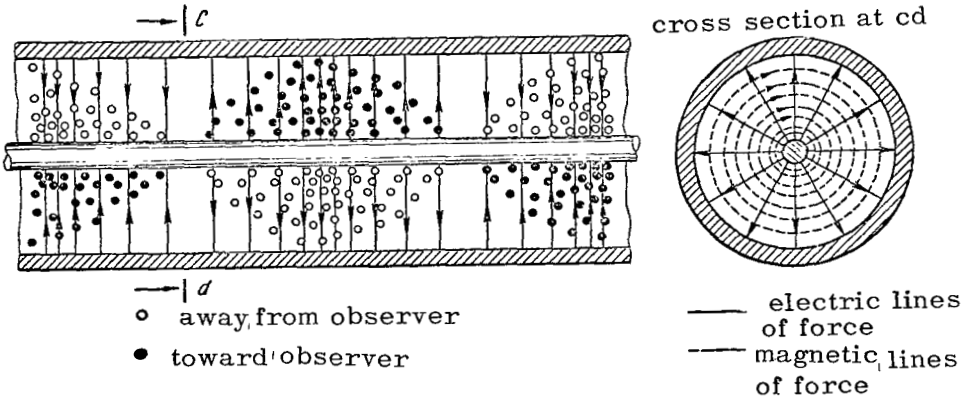


Fig. 241. Diagram of Electromagnetic Waves Propagated Along a Coaxial Cable.

The transmission of UHF electromagnetic oscillations from /291
a magnetron to a load also has some peculiar aspects. Transmission of oscillations of suitable frequency in a conventional exposed two-conductor wire is difficult because the distance between the wires is small relative to the wavelength, so that such a system causes considerable radiation into the surrounding space. Transmission is much better through a wire which is surrounded by shielding, i.e., a coaxial feeder.

Figure 241 shows a schematic representation of an electromagnetic wave formed along a coaxial cable. At the right is a cross section of a cable and the lines of force of the electromagnetic field located within it. The lines of force of an electric field (solid lines) run radially between the central wire and the shield of the feeder; the lines of force of the magnetic field (dotted lines) form solid circles located in the plane perpendicular to the cross section of the feeder.

However, the transmission of electromagnetic waves along a coaxial cable involves losses in the dielectric. To get rid of the latter at very high frequencies, transmission is conducted along a special type of conductor consisting of only one conductor called a waveguide. A waveguide (Fig. 242) is a hollow metal tube of circular or (more often) rectangular cross section, with smooth walls which conduct current very well. The action of the waveguide is based on the fact that the electromagnetic wave propagated at one end or it travels by multiple reflection from the walls and by interference to form one common wave which is propagated along the axis of the waveguide.

One of the possible forms for a suitable wave is represented schematically in Figure 242: (a) for a waveguide of circular cross section and (b) for one with a rectangular cross section. In both cases, the lines of force of the electric field are located in directions perpendicular to the axis of the waveguide. The magnetic lines of force form closed loops oriented along the axis of the waveguide. /292

Figure 243 shows reflection and waveguide type radiators used on centimeter wavelengths. The reflector type radiator (Fig. 243, a) consists of a metal hemispherical reflector 4, in the center of which is an emitter 3. The emitter is connected to the central conductor of a coaxial feeder 2, while the reflector is connected to the shield of the feeder. In the magnetron, the central conductor of the feeder is connected to loop 1 of the circuit, located in one of the resonators. The shield of the feeder is grounded along with the anode.

The waveguide-type radiator (Fig. 243, b) consists of a hollow tube 3 which serves as the waveguide; at one end is an emitter 1, connected to the loop in the magnetron. The connections between the waveguide and the loop is regulated by dampers 2. The radiator is the other open end of the waveguide.

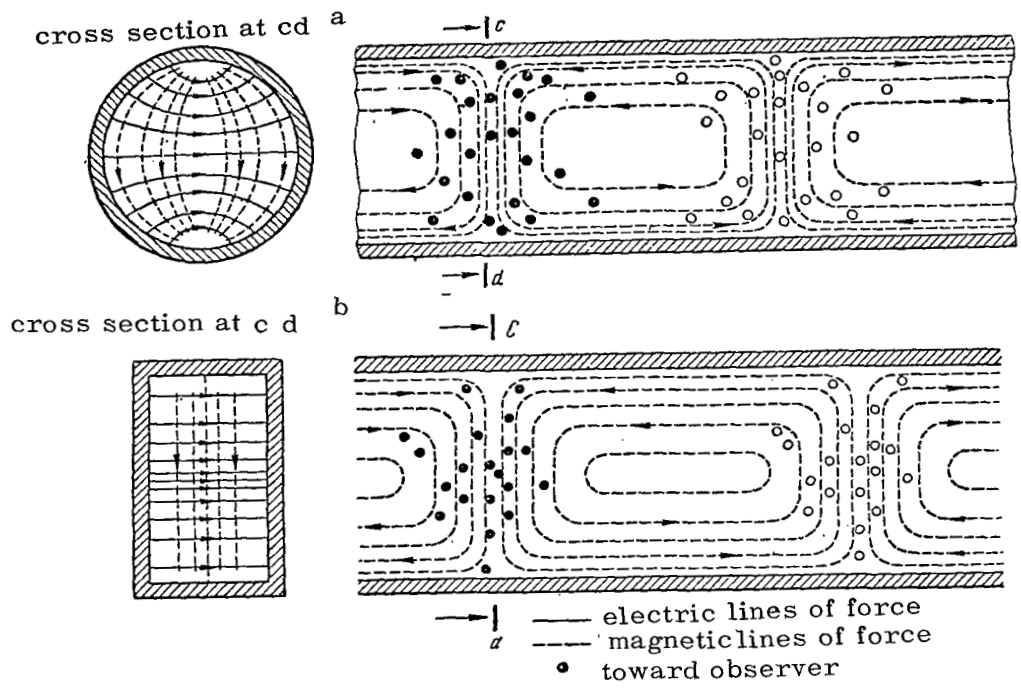


Fig. 242. Diagram of Electromagnetic Wave Propagated Along a Waveguide. (a) Circular Cross Section; (b) Rectangular Cross Section.

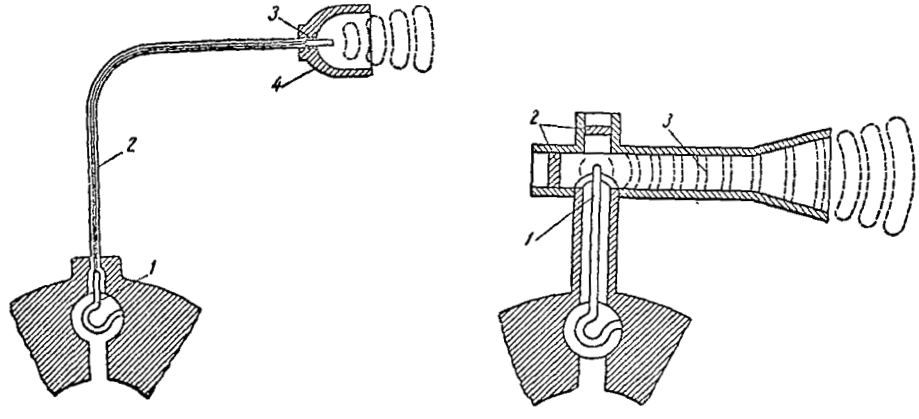


Fig. 243. Diagram of Microwave Radiators. (a) Reflector Type; (b) Waveguide Type.

§ 2. APPARATUS FOR MICROWAVE THERAPY (STATIONARY MODEL "LUCh-58")

The apparatus for microwave therapy has a relatively simple design. The heart of the instrument is a magnetron located between the poles of a powerful permanent magnet, made of special magnetic alloys. The magnetron is connected by a coaxial cable to the radiator. The balance of the apparatus consists of a power supply for the magnetron as well as the necessary auxiliary and regulating equipment.

In 1958, the VNIIMIO developed an apparatus for microwave therapy with the designation "Luch-58", which was produced by the Union Factory of the EMA. The following are the basic data for the apparatus: (1) the wavelength is 12.6 cm (frequency 2375 ± 50 MHz); (2) the maximum output power is 150 W; (3) the dimensions of the apparatus (together with the support for the radiator) are 440 x 620 x 1500 mm. The instrument weighs approximately 45 kg and draws 500 VA.

The apparatus must be grounded during operation.

The schematic diagram of the apparatus (one of the first models) is shown in Figure 244. The generator of electrical oscillations is magnetron V_3 with air cooling, located between the poles of the powerful permanent magnet M with a field intensity of approximately 1800 Oe. The output of the magnetron is connected by a flexible coaxial cable K to radiator I. /293

The magnetron is powered by direct current from a full-stage rectifier operating with high-voltage kenotrons. The supply voltage of the anode circuit of the magnetron is approximately 2100 V.

The power of the magnetron is adjusted by changing the anode voltage with a switch controlling resistors 10-15 which are connected in series in the anode supply circuit of the magnetrons. The resistors are switched by double switch Sw_2. The second level of the switch is used for simultaneously switching resistor 16 which is connected in series with the power supply to the magnetron filament. As the output power increases, the filament voltage decreases, so that at a power of 110 W and above the filament power is cut off completely. At this time, the cathode is heated by reverse bombardment of electrons. /294

The power supply of the circuit contains power transformer Tr. The primary winding of the transformer is divided for connection to 127 or 220 V (the changeover is made by inserting the proper fuses on the transformer panel), and fitted with voltage compensator PK_1. The compensator ensures normal operation of the apparatus with variations of line voltage between 95 and 137 V and 190 to 232 V, respectively. Voltmeter PP_2 and fan B for cooling the magnetron are connected to the primary winding.

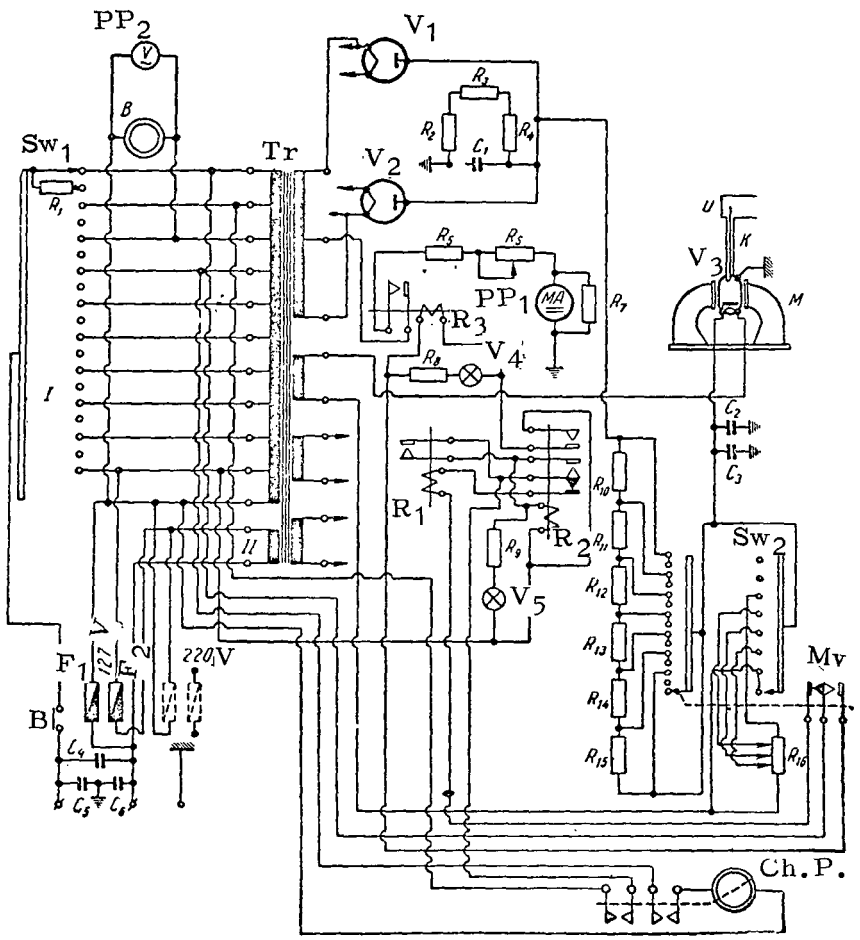


Fig. 244. Schematic Diagram of "Luch-58" Apparatus for Microwave Therapy.

The step-up winding powers the rectifier which uses two high-voltage kenotrons V_1 and V_2. The voltage pulsations are smoothed by capacitor 1, shunted by leak resistors 2-4. The negative pole of the rectifier circuit runs through resistors 10-15 to one of the filament leads of the magnetron V_3. The center tap of the step-up winding is grounded through the contacts of relay R_3, resistors 5 and 6 and milliammeter PP_1, which is used to measure the output power (as a wattmeter).

The auxiliary part of the circuit contains a group of relays similar to those used in the UDL, and DKV apparatus, whose operation has been described previously. The difference in this circuit is the inclusion of the windings of thermal relay R_1 and intermediate relay R_2 through the contacts of timer ChP, and the coil of relay R_3 which turns on the high voltage, through the contacts of microswitch Mv, which is connected to the control of switch Sw_2. This group of relays is equipped with pilot lights: V_5 in the circuit of the intermediate relay R_2 and V_4 which is connected to the circuit of relay R_3 which turns on the high voltage.

Specifications for Schematic Diagram of "Luch-58" Apparatus Magnetron

V_3	Magnetron
V_1-V_2	High-voltage kenotron, V1-0.1/30

Resistors

R_1	Wire-wound	R_{10}	PEV-25, 620 Ω
R_2-R_4	VS-2, -.68 MΩ	R_{11}	PEV-25, 1000 Ω
R_5	PEV-30, 820Ω	R_{12}	PEV-25,2000 Ω
R_6	PEVx, 510Ω	R_{13}	PEV-25, 3000 Ω
R_7	Wire-wound	R_{14}	PEV-25, 7500 Ω
R_8-R_9	VS-2, 100Ω	R_{15}	PEV-25, 20 000 Ω
		R_{16}	PEV-25x, 100 Ω

Capacitors

C_1	KBG, 3 kV, 1 μf	C_4	KBG-I, 600 V, 2200 pf
C_2	KBG-Ts, 3 kV, 0.1 μf	C_5-C_6	KBG-2, 600 V, 0.01 μf
C_3	KVKT-6, 470 pf	S_1-S_2	Fuse PN-5
V_4-V_5	Incandescent lamp MN-18	Tr	Transformer
I	Radiator	Sw_1-Sw_2	Switch
K	Coaxial cable	B	Ventilator VN-3, 127 V
M	Magnet	PP_2	Voltmeter E-421, 0-150 V
Mv	Microswitch	PP_1	Wattmeter (milliammeter M4-2)
ChP	Timer		
R_1	Thermal relay		
R_2-R_3	Electromagnetic relay		

The apparatus operates as follows. When the compensator knob (Sw_1) is turned from the zero to the first position, the line voltage is admitted to the primary windings of the transformer. The fan is turned on and power flows to the filament of the magnetron and the kenotron. Further rotation of the compensator knob (to positions 2-10) controls the nominal line voltage, checked by the voltmeter whose needle must be on the red part of the scale. /295

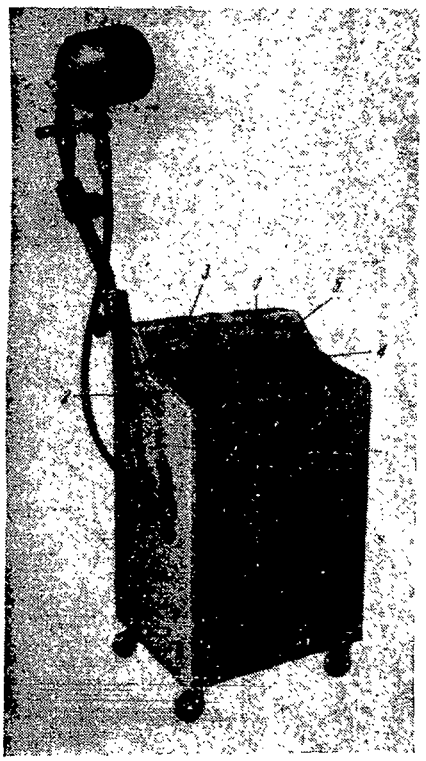


Fig. 245. General View of "Luch-58" Apparatus.

The timer must now be set for the duration of the treatment. This closes the blocking contacts of the timer, allowing the voltage to flow to relay R_2.

If the power control knob Sw_2 is located in the zero position, then the supply voltage will flow through the closed contacts of microswitch Mv to thermal relay R_1. After the required time has elapsed (1-1½ min), the relay operates and allows the voltage to flow to the intermediate relay R_2. This causes pilot light L_5 to light. The intermediate relay operates and allows the current to flow to the actuacting relay R_3.

The power regulator can now be turned from zero to the first operating position. This closes the blocking contacts of the microswitch in the circuit of relay R_3 and the latter operates to transmit the high voltage to the magnetron. At the same time, the red pilot light V_5 lights up. Then the power regulator knob is moved to the next position so that the required intensity of radiation is obtained, as indicated by the reading on wattmeter PP_1.

When the treatment is over, the timer opens its blocking contacts and cuts off the power to relay R_3, thus shutting off the high voltage. The power control knob must then be returned to the zero position.

A general view of the apparatus is shown in Figure 245. The apparatus is mounted in a metal chassis, mounted on rollers. The apparatus is equipped with a hinged arm on the left side which serves to support the radiator. The top of the cabinet is used as

the control panel. The following equipment is located on it: in the center is the timer 1, to the left of it is the knob for the voltage compensator 2 and below that is voltmeter 3. Next to the latter is the green pilot light, and to the right of it is power regulator 4; below that is wattmeter 5 and beside that is the red pilot light.

Figure 246 is an internal view of the apparatus: at the bottom is transformer 1, in front of it is rectifier tube 4. To the left is relay unit 3 and still further to the left is fuse panel 2. (Next to this panel there is a high-voltage capacitor 5 for the rectifier filter). Above these, in the middle of the cabinet, are magnet 6 and magnetron 7 between the poles of the latter; the high-frequency lead of the latter is connected to the coaxial cable 8. /296

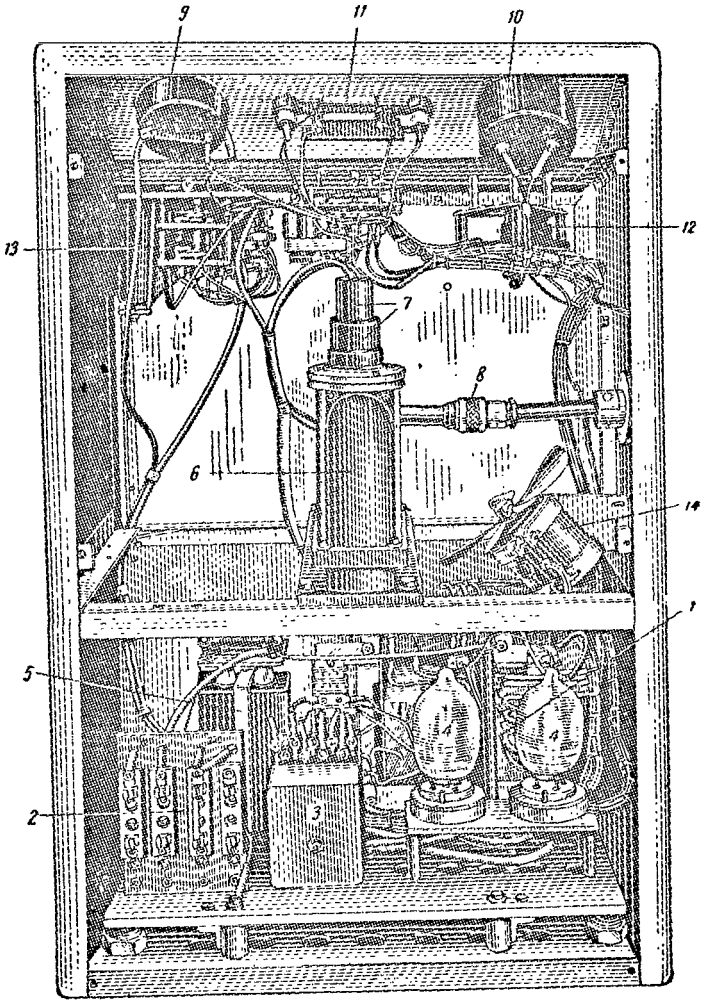


Fig. 246. Location of Parts in the "Luch-58" Apparatus.

On the right is ventilator 14 for cooling the magnetron.

At the top, on the back of the control panel, there are power switch 13 and wattmeter 9, timer 11, and voltage compensator 12 and voltmeter 10.

A general view of the magnetron is shown in Figure 247. In the figure we have (1) the body (anode) of the magnetron, (2) radiator fins for cooling, (3) filament leads, (4) flange for mounting magnetron, (5) high-frequency energy lead, (6) getter (support containing absorptive material).

Figure 248 shows the set of radiators (I-IV), which are supplied with the apparatus. The radiators are of waveguide type. Each radiator constitutes a part of waveguide 1, which is open at one end and closed at the other. The waveguides are excited by means of electrode 2, located perpendicular to the axis of the waveguide at a distance of 1/4 wavelength from the closed end. The output of the waveguide is closed by cap 3 made of high-frequency dielectric material. /297

The treatment proceeds as follows. Depending on the configuration and location of the region to be irradiated, a corresponding radiator is chosen and mounted on the holder of the apparatus. The patient is placed in a comfortable position, and the radiator is set at a distance of several centimeters above the surface of the body (it is not necessary to remove the clothing from the area to be irradiated).

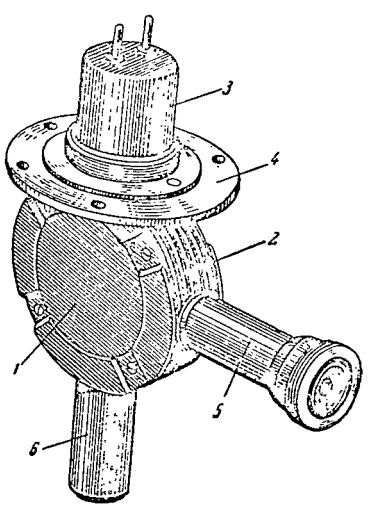


Fig. 247

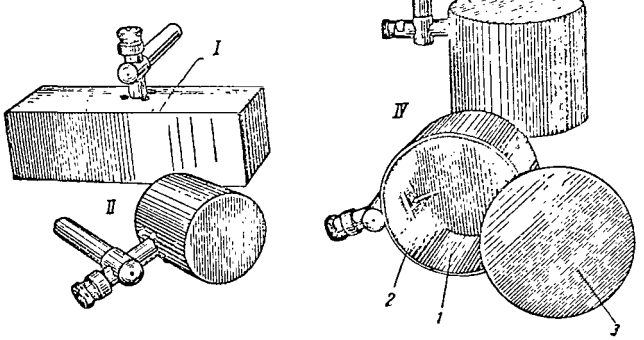


Fig. 248

Fig. 247. Magnetron for "Luch-59" Apparatus.

Fig. 248. Set of Radiators for "Luch-58" Apparatus.

Then, after checking that the power regulator and voltage compensator controls are set to zero, the plug is inserted in the apparatus. The compensator knob is set to a position corresponding to the position of the voltmeter needle on the red area, while the timer is set for therequired duration of treatment. After 1-1.5 min, the relay operates and the green lamp lights. The power regulator knob is then turned to the first operating position (at which time the red pilot light goes on). The required output power is then set.

The intensity of the dose is determined by the sensation felt on the surface of the skin.

The apparatus is turned off automatically when the timer returns to zero. It is then necessary to set the power regulator knob back to zero and to make preparations for the treatment of /298 the next patient.

When all treatments are complete, the voltage compensator knob is returned to zero and the line cord is disconnected from the wall.

§ 3. APPARATUS FOR MICROWAVE THERAPY (PORTABLE MODEL "LUCh-2")

The portable apparatus for microwave therapy, designated by "Luch-2", was developed by VNIIMIO and produced by the L'vov Factory of Medical Instruments.

The apparatus is intended for using microwaves to treat small areas of the body by the contact method. The small weight and size of this instrument permits use at the patient's bedside either at home or in the clinic.

The essential data of the apparatus are as follows: the wavelength of the electric oscillations produced by the magnetron generator is 12.6 cm (frequency equals 2375 MHz $\pm$ 2%). The output power is adjustable in seven steps from 2 to 20 W.

The nominal voltages for the input are 127 or 220 V. By using a voltage compensator, normal operation of the apparatus can be ensured with deviation of the line voltage from the nominal value: at 127 V, from +5% to -25% and at 220 V from +5% to -15%. The maximum power drawn by the apparatus is 130 VA.

The overall dimensions of the apparatus are 400 x 270 x 200 mm and it weighs approximately 10.5 kg including the set of radiators.

The schematic diagram of the apparatus is shown in Figure 249. The generator of VHF electrical oscillations is a magnetron V_1 located between the poles of a small permanent magnet M. The intensity of the magnetic field between the poles of the magnet is 1000 Oe. The required air cooling of the magnetron anode is

accomplished by means of a four-bladed fan D powered by a type DAP electric motor. The energy output of the magnetron is fed through a flexible coaxial cable F via the high-frequency connection on the control panel to radiator A.

The magnetron anode is powered by a rectifier using voltage doubling with germanium rectifiers D_1-D_2 and capacitors 1-2. The rectifier is powered by the high-voltage winding of power transformer Tr.

For step-wise regulation of the power in the anode circuit, resistors 4 and 9 controlled by switch S_2 are connected to the magnetron. The operating regime of the generator can be adjusted by means of variable resistors 1 and 2 at the factory or when replacing the magnetron.

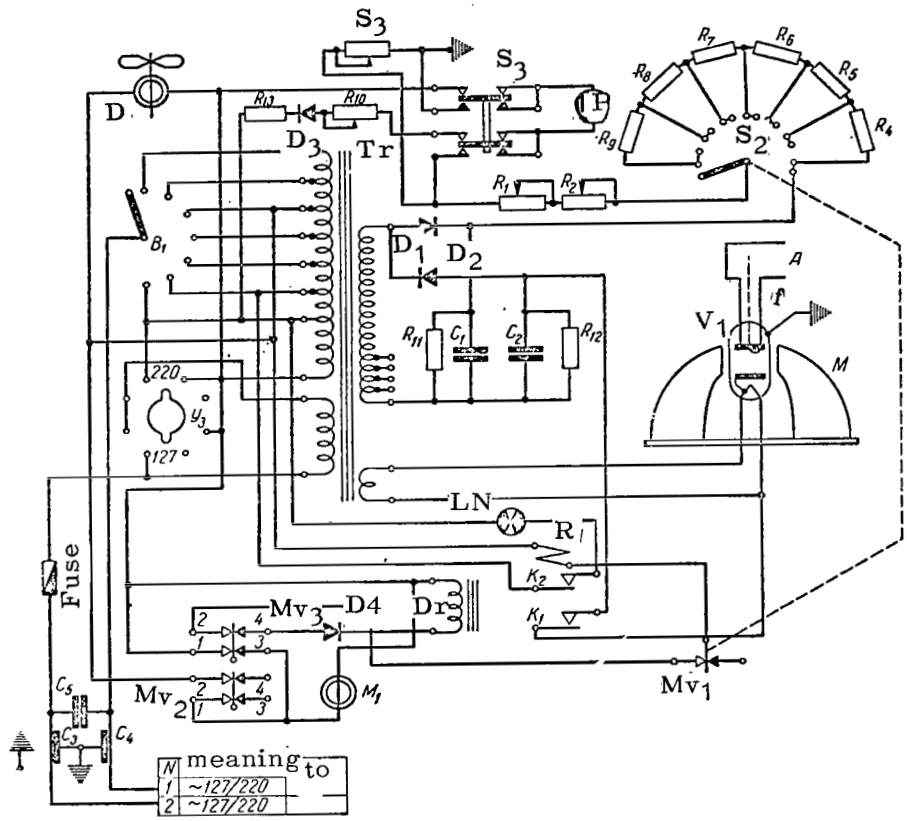
The wiper of power regulator S_2 is grounded through wire-wound resistor 3, which acts as a shunt for milliammeter IP, connected to it through the normally closed contacts of pushbutton switch S_3. The milliammeter measures the anode current of the magnetron and serves to indicate the output power of the apparatus. The scale of the meter is graduated in watts.

The primary winding of the power transformer is divided to permit operation from 127 or 220 V. Switch Y_3 is used to change from one input voltage to another. A portion of the primary winding has leads for step-wise compensation of the line voltage, controlled by switch S_1. The compensator ensures normal operation of the apparatus at line voltages between 95-137 V and 190-232 V.

The line voltage reaching the apparatus is monitored by milliammeter IP. When pushbutton S_3 is depressed, the meter is connected to the primary winding through semiconductor germanium diode D_3, quenching resistor 13 and adjustable resistor 10. The scale /299
of the meter has a red area which corresponds to the nominal line voltage with an error of $\pm$ 3%.

Electromagnetic relay R is used to adjust the high-voltage circuit supplying the magnetron; its normally open contacts K_1 are connected to the negative pole of the rectifier and the cathode of the magnetron. The relay coil is powered by the primary winding of the transformer through microswitch Mv_1 which is mechanically linked to the power regulator S_2 and the microswitch Mv_3 of the timer. The second pair of contacts of K_2 of relay R are connected to the power supply leading to pilot light LN.

The timer is based on a synchronized motor SD-2 (M_1) which operates at 2 rpm. The armature of the motor is connected through a system of gears to the knob for setting the timer, which is in turn linked through a camshaft to microswitches Mv_2 and Mv_3.



switch for input voltage

Fig. 249. Schematic Fiagram of Luch-2" Apparatus.

The electric motor is connected to the primary winding of the transformer through the normally open contacts 1-2 of microswitch Mv_2. Buzzer Dr is connected in parallel with the electric motor to the normally closed contacts 3-4 of microswitch Mv_3.

The power supply of the apparatus is fitted with a protective unit to suppress radio interference, consisting of two capacitors 3-4 and a capacitor 5.

The apparatus operates as follows. When the knob of capacitor B_1 is turned from the zero to the first position, the line voltage reaches the primary winding of the transformer. This turns on the ventilating fan and supplies voltage to the filaments of the magnetron. Further rotation of the compensator knob turns on the normal voltage supplied to the apparatus. This is monitored by a meter connected to the primary winding by pushbutton switch S_1. By turning the timer knob, the required length of treatment can be set. This closes contacts 1 and 2 of microswitch Mv_2 and the supply voltage reaches electric motor M_2. Contacts 3 and 4 of the microswitch Mv_3 open and the voltge to the buzzer Dr is cut off. When the power regulator knob S_2 is turned from the zero to the first position, microswitch Mv_1 is activated connecting the voltage to relay R_1; the relay operates and the high voltage reaches the magnetron. This causes pilot light LN to go on. The power regulator knob is then advanced to the next position so that the wattmeter (milliammeter IP) shows the required generator power.

When the time required for treatment has elapsed, microswitch Mv_3 operates. This causes contacts 1-2 to open, interrupting the circuit to the windings of relay R_1 and removing the high voltage from the magnetron. At the same time, contacts 3 and 4 close to complete the circuit to the buzzer which gives an audible signal indicating the end of the treatment. After 30-40 sec, microswitch Mv_2 operates. Contacts 1 and 2 open, cutting off the supply to the electric motor and buzzer. The power selector knob is set to zero and the apparatus is ready for another treatment.

Specification for Schematic Diagram of Luch-2 Apparatus

Resistors

R_1-R_2	PPZ-11, 330Ω±5%	R_7-R_8	PZV-10, 5100 Ω±10%
R_3	Wire-wound	R_9	MLT-2, 68 Ω±10%
R_4	PZV-7, 1200 Ω±10%	R_{10}	PPZ-11, 6800 Ω±10%
R_5	PZV-7, 1500 Ω±10%	R_{11}-R_{12}	MLT-1, , MΩ±10%
R_6	PZV-10, 3000 Ω±10%	R_{13}	MLT-2, 2kΩ±10%

Other Parts

V_1	Magnetron M-62	Mv_1	Microswitch with roller
M	Permanent magnet	Mv_2-Mv_3	Pushbutton microswitches
C_1-C_2	Capacitor MBGP, 1 kV, 1 f	S_1-S_2	Switches
C_3-C_5	Shielded unit ZB-1, 220 V, 10A	S_3	Pushbutton switch
		Y_3	Switch
LN	Incandescent lamp MN-14, 6.3 V	IP	Milliammeter M-358, 0-10 mA
Tr	Power transformer	F	Fuse PM-2
D_1-D_2	Rectifier D-1001	M_2	Ventilator, electric motor DAP, 127 V
D_3-D_4	Semiconductor diode D-7Zh	Dr	Buzzer
		A	Radiator
R	Electromagnetic relay RPT-100		
F	Coaxial cable RK-75-4-16		
M_1	Electric motor SD-2, 127 V		

The design of the apparatus is as follows. The instrument, as /301 shown in Figure 250, is mounted in an aluminum cabinet with two panels (front and back).

On the front panel, which serves as the control panel, there are a meter 1, pilot light 2, timer knob 3, power selector switch 4, pushbutton switch 5 for the meter, socket 6 for plugging in the high-frequency lead, and knob 7 for compensating the line voltage.

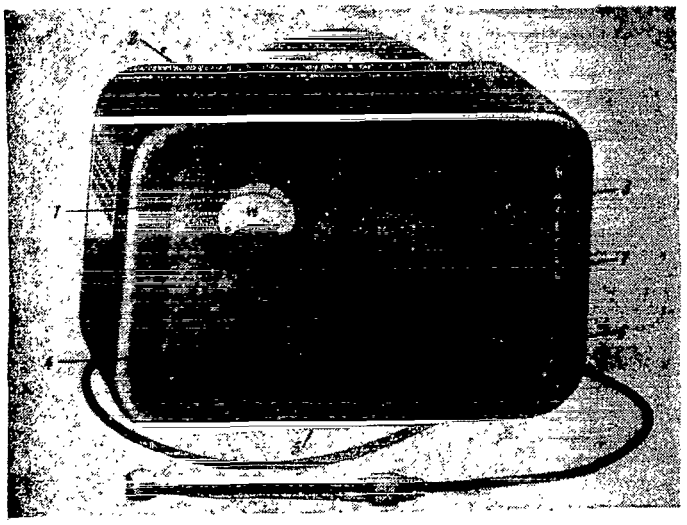


Fig. 250. General View of "Luch-2" Apparatus.

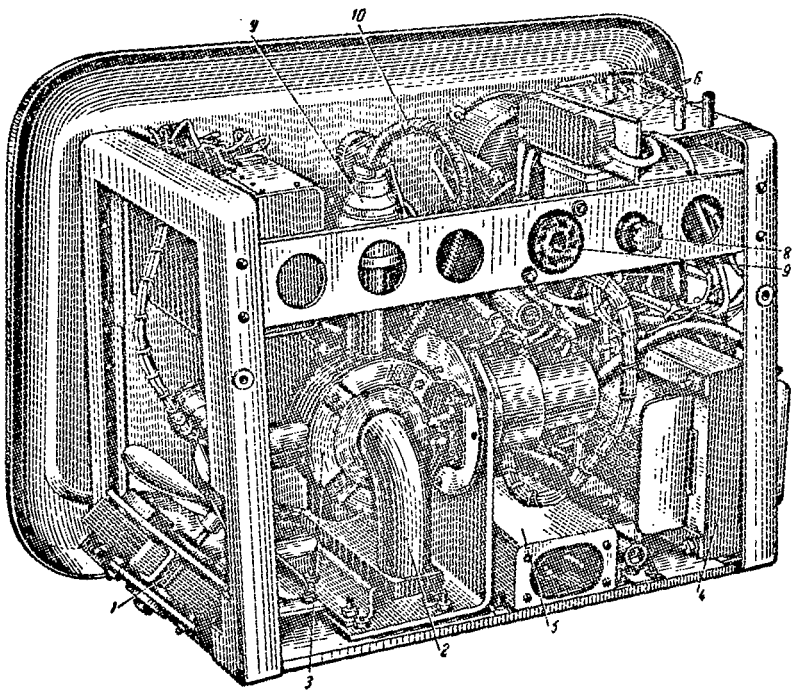


Fig. 251. Location of Parts in the "Luch-2" Apparatus.

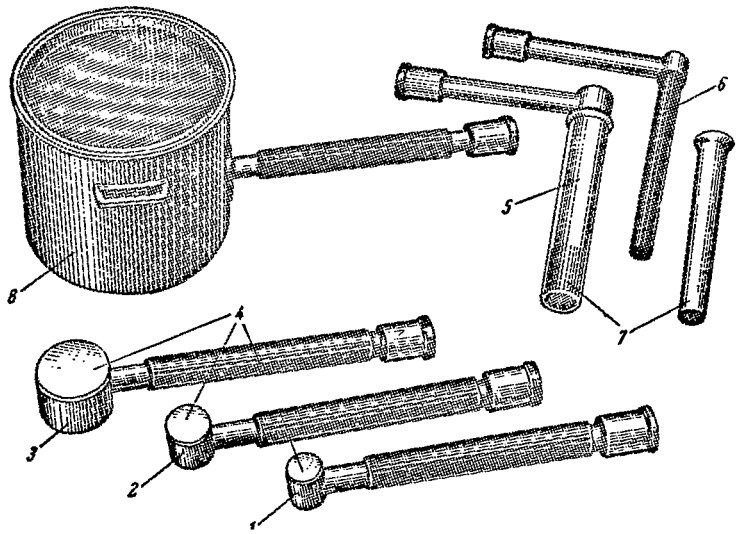


Fig. 252. Set of Radiators for "Luch-2" Apparatus.

Figure 251 shows the apparatus with the cabinet removed. The parts of the electrical section of the apparatus are located on a chassis mounted on the front panel of the cabinet. Ventilator 1 and the magnetron generator consisting of permanent magnet 2 and magnetron 3 are mounted on a separately removable unit in the lower left part of the cabinet. At the bottom right are power transformer 4 and line filter 5. The relay, rectifier 6 and shunt for adjusting the milliammeter are located in the upper right section of the cabinet. A metal support holds fuse 8 and socket 9 for the line cord for connecting the apparatus to the source of voltage. A high-frequency socket 9 and a flexible coaxial cable 10 are used to connect the energy output from the magnetron to the socket of the high-frequency jack on the front panel of the apparatus.

Figure 252 shows the set of radiators provided with the apparatus. Radiators 1, 2, and 3 are circular waveguides 1.5, 2, and 3.5 cm in diameter, respectively. The waveguide is filled with a high-frequency ceramic and activated by an electrode which is inserted in the ceramic perpendicular to its axis. The ceramic which protrudes from the open end of the waveguide is covered with a thin cap made of high-frequency dielectric. The cap can be cleaned with a cloth moistened with a disinfectant. The rigid coaxial cable which powers the waveguide is covered with rubber on the outside and is used as the handle for the radiator. The handle ends in a small high-frequency socket for plugging in the coaxial cable.

The electrodes designed for use in body cavities (vaginal 5 and rectal 6) differ in that the ceramic extends beyond the waveguides, forming a dielectric rod. The rod is covered by a removable cap 7 which permits disinfection with liquid. The shape of the rod is conical. The diameter of the base of the cone in the case of the vaginal electrode is 2 cm; it is 1.5 cm for the rectal electrode. The rod is 13.5 cm long. /303

In addition to being of different diameter, the vaginal and rectal electrodes differ in the shape of the fields which they produce. The vaginal electrode produces a field which is concentrated at its tip. The rectal electrode produces a field along the entire length of the rod. In addition to these ceramic radiators, the apparatus is also supplied with a radiator 8 which is 11.5 cm in diameter and has no ceramic covering. It is used for irradiation of relatively large portions of the body, also by the contact method. The radiator can be held in the hand or can be fastened to the body by means of a rubber belt passed through the loops on the sides of the radiator.

Treatment is given as follows. Depending on the size and location of the region to be irradiated, the proper radiator is chosen and connected to the high-frequency cable; the other end of the cable is connected to the output jack on the panel of the apparatus. The radiator is placed directly against the surface of

the body which is to be irradiated. Checking to be sure that the power regulator and voltage compensator are set to the zero position, and being sure that the apparatus is grounded and the knob for selecting the proper input voltage is in the correct position, the line cord is plugged into the wall. The voltage compensator knob is set to the position corresponding to the nominal voltage for the apparatus. The proper value can be checked on the meter by pressing the pushbutton switch. After waiting 1 min, the timer knob is turned to select the required length of time for treatment and the power regulator knob is turned to the first position. The required output power is then selected. The dosage depends on the power selected; the latter is largely dependent on the state of the patient. In all cases, there must be no sensation of painful heat or burning.

The output power is disconnected automatically when the timer runs out.

The power regulator knob is returned to the zero position, after which a new treatment can be given. When work with the apparatus is over, the voltage compensator knob is returned to the zero position and the line cord is disconnected from the wall.

CHAPTER V

APPARATUS FOR ULTRASONIC THERAPY

PART 1

PHYSICAL BASES AND METHODS FOR CARRYING OUT THE PROCEDURES OF ULTRASONIC THERAPY

In the preceding discussion, we became acquainted with electromagnetic vibrations and waves which form the basis of a variable high-frequency electromagnetic field. This electromagnetic field acts on the charges and particles (atoms and molecules) of materials and on the tissues of organisms in particular. /304

Mechanical vibrations and waves, i.e., the phenomena which are connected with the vibration or movement of particles of materials on the whole, are examined in this chapter.

Mechanical vibrations and waves at frequencies lower than 16 Hz are called infrared. The therapeutic application of such vibrations can be seen in the example of vibratory massage. Mechanical vibrations and waves in the frequency range from 16 to 20,000 Hz are called sonic and are detected by the ear, causing a sensation called sound. Mechanical vibrations and waves at frequencies greater than 20 kHz are called ultrasonic (or simply ultrasound), and cannot be detected by the ear. The upper limit for the frequency of ultrasonic vibrations is not fixed. At the present time, we can obtain ultrasonic vibrations at frequencies of several million Hz.

Sonic and ultrasonic waves are longitudinal waves, i.e., the vibrations in the particles occur in the same direction as the wave propagation. Hence, a sonic or ultrasonic wave can be viewed as a combination of segments: the particles of the material which alternate and move in the direction of the wave motion. In solid substances, there can also be transverse sonic or ultrasonic waves in addition to the longitudinal waves. The distance between the center of the two adjacent segments in which there is thickening or thinning of the material is called the length of the ultrasonic wave. The wave length λ depends on the period T or the frequency of the oscillations ν and the propagation rate V of the wave in a

given medium: $\lambda = \frac{V}{\nu} = VT$. The propagation rate of sonic and ultrasonic waves in air is about 3330 m/sec; in water and tissue it is 1500 m/sec.

The source of ultrasonic waves is usually a body which is oscillating at a certain frequency. To obtain ultrasonic vibration at a frequency of several tens of kHz, we can use the phenomenon of magnetostriction, which means that the action of an alternating magnetic field produces some kind of change in the size of a disc /305
or rod made of ferromagnetic material. The periodic lengthening and shrinking of the rod under these conditions, for example, produces an oscillatory motion of the air particles near it, so that a sonic or ultrasonic wave is produced depending on the frequency of the oscillations.

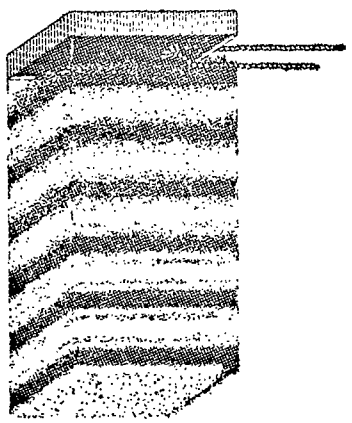


Fig. 253. Diagram Showing Formation of Ultrasonic Waves.

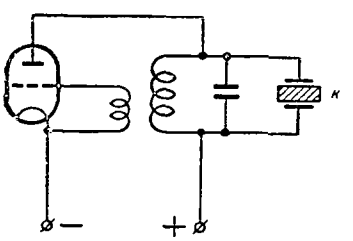


Fig. 254. Elementary Diagram of an Ultrasonic Generator.

Ultrasound of relatively high frequency, on the order of 800-3000 kHz, is the only type routinely used in medicine; this sound is produced nearly exclusively by means of the so-called reverse piezoelectric effect. The reverse piezoelectric effect can be understood as follows: in many crystals (quartz, Rochelle salt, barium titanate, etc), the influence of an electrical field produces a certain mutual displacement of polar groups of atoms forming the basic structure of material, producing corresponding changes in the size of the crystal.

For example, if a strip cut in a certain way from a quartz crystal is placed between electrodes which act as the two plates of a capacitor, to which an alternating electrical voltage is applied, the strip will be deformed by compression and expansion in accordance with the frequency of the applied voltage. Periodic changes at sufficiently high frequency in the thickness of the strip will produce corresponding oscillations in the particles of the medium in contact with the surface of the strip; these oscillations

will then be propagated into the surrounding medium in the form of an ultrasonic wave (Fig. 253).

Ultrasonic waves are like sonic waves in that they obey the same laws in principle, but since their wave lengths are tens and hundreds of times shorter than those of sonic waves, they have several specific features. In particular, ultrasonic waves (especially at high oscillation frequencies) are propagated in a certain direction, are easy to focus, and are almost completely reflected at the air boundary.

A device used for ultrasonic therapy consists mainly of a generator of electrical oscillations of the proper frequency and low power, whose oscillator circuit contains a quartz or barium titanate element for radiating the ultrasonic vibrations; the latter is called a piezoelectric transducer (Fig. 254). The transducer is usually located in a separate head (or radiator), connected to the apparatus by a cable.

The radiator, represented schematically in Figure 255, consists of a cylindrical metal tube 4 on the end of which (1) is located a quartz disc 6. The disc is fastened to the end by a special material (epoxy resin, for example). In addition, the disc is held in place by means of a clamp 3 and spring 7. The base 1 is fastened to the chassis by means of a nut 5 and serves as a resonator. For this reason, it must have a constant and carefully controlled /306
thickness, and have a certain ratio to the wave length of the ultrasonic oscillations. On the other side, the disc touches a thin film of air which is always below the clamp 3. The ultrasonic wave which is propagated from the front of the disc in the operating direction.

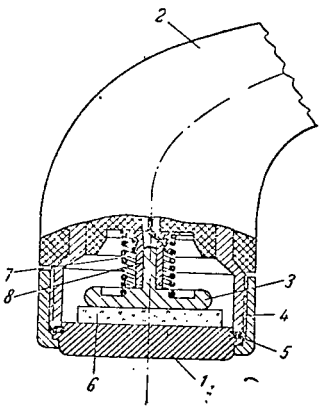


Fig. 255. Diagram of Ultrasonic Radiator for Therapeutic Purposes

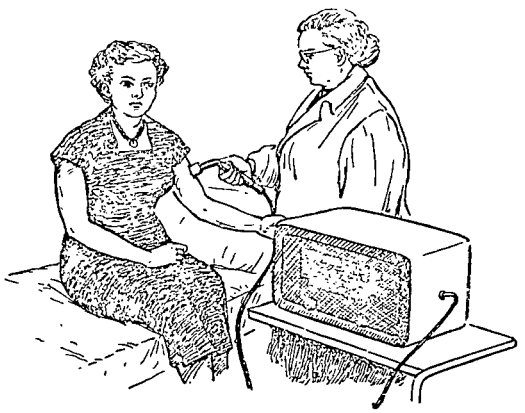


Fig. 256. Procedure for Using Ultrasonic Radiation.

The radiator unit (head) is mounted in the handle 2, held by the person administering the treatment. The wire from the generator is inside the handle. Bushing 8 holds the wire in contact with clamp 3, which serves as one of the electrodes; the second electrode is the body of the head, to which the shielding of the power cable is connected.

The effect of ultrasound on tissue is usually achieved by placing the flat surface of the head of the radiator against the area to be treated. To prevent reflection of waves from the boundary with the air beneath the radiator, a layer of material such as petroleum jelly is spread on the surface of the skin.

The contact method is used for treating relatively flat, soft areas of the body and can be either fixed (stable) or movable (labile): the head of the radiator is then moved with a gentle massaging motion over the entire surface of the area being treated (Fig. 256). In addition to the contact method, the effect can also be produced through water: either by means of a bath, or with tubes or rubber balloons filled with water.

The treatment of the extremities is usually performed in a bath of hot water in which the extremity and radiator are placed. The radiator is either held in a fixed position a short distance from the surface of the body, or else it is moved slowly and evenly about over the surface being treated. Sometimes a flat metal reflector is placed in the bath to direct the waves from the radiator to the surface being treated.

Tubes are used to treat small areas of the body (Fig. 257). Tube 3, which has openings of suitable sizes, is set in place and filled with warm water. The top of the tube is then covered by a rubber membrane, and the radiator head 1 is attached to the latter by means of a special guide 2. It is possible to use a flexible rubber balloon instead of this tube; the balloon is filled with warm water, tied off, and placed on the area to be treated. The radiator head is placed against the balloon. Only a very slight sensation of heat is felt in the area being treated with ultrasound during treatment. /307

The effect of ultrasonic vibrations on the tissue of an organism is complex; it can be divided into three basic components. These are the mechanical, thermal, and chemical effects. The mechanical effect is related to the direct action of vibrations produced by the alternate compression and relaxation of the particles in the tissue, i.e., a unique form of micro-massage. The thermal effect is directly proportional to the magnitude of the energy of the oscillations which are absorbed in a given tissue. The chemical effect is related to the changes which occur in the intensity of oxidation processes under the influence of the oscillations. It is also possible to produce ions in tissues and to cause ions to lose their charges, as well as a number of other phenomena.

The frequency of the ultrasonic vibrations which are usually used for therapeutic purposes is usually between 800 to 3000 kHz. The power of an ultrasonic wave reaching a unit working surface of the radiator is called the specific power or intensity of the ultrasound. The maximum intensity of the ultrasound used by us for therapeutic purposes is 2-2.5 watts/cm^2. The area of the radiator head in various instruments varies from 4-12 cm^2. Hence, the total ultrasonic power of the radiator in small instruments is 8-10 watts and 25-30 watts in large instruments.

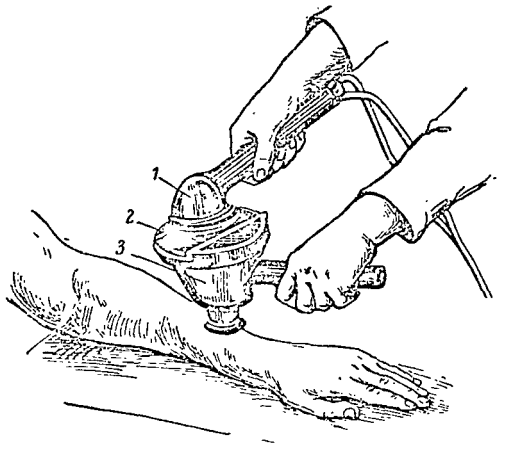


Fig. 257. Diagram Showing Tube Used for Ultrasonic Radiation.

PART 2

APPARATUS FOR ULTRASONIC THERAPY

§1. APPARATUS FOR ULTRASONIC THERAPY (PORTABLE MODEL UTP-1)

A portable instrument for ultrasonic therapy has been developed by the VNIIMIO and is being produced by the Union Factory of the EMA.

The basic data on the apparatus are as follows: frequency of ultrasonic vibrations, 830 $\pm$ 14 kHz; in apparatus which have been produced since 1963 in accordance with the new standard, it is 880 kHz $\pm$ 1%.

The maximum power for irradiation in water is 8-10 watts. The maximum specific power is 2-2.5 watts/cm^2 (the area of the radiator is 4 cm^2). The power can be regulated in ten steps.

The apparatus operates in constant as well as pulsed regimes. /308 The pulse durations are 10 $\pm$ 2 msec, 4 $\pm$1 msec and 2 $\pm$ 0.5 msec. The repetition frequency of the pulses is 50 Hz.

The apparatus is powered by a source of alternating current at a frequency of 50 Hz and voltages of 127 and 220 volts, with variations of +5%, -15%.

The maximum power drawn from the circuit is 165 VA.

The overall dimensions of the cabinet of the apparatus are 320 x 420 x 135 mm. It weighs approximately 13 kg.

The schematic diagram is shown in Fig. 258. The high-frequency generator for powering the quartz piezoelectric transducer is con-

nected in the circuit with self-excitation using a GH-50 (V_5) pentode. The oscillating circuit of the generator with capacitor feedback consists of an inductance coil 2, the capacitance of a high frequency cable by which the quartz piezoelectric transducer is connected to the generator, and capacitor 14. To increase the high-frequency voltage in the transducer to the required level (2.5 kV), the generator tube is connected to parts of the windings of the inductance coil 2. To adjust the generator to the frequency of the piezoelectric transducer, an adjustable capacitor 1 is used.

The automatic bias is formed on resistors 43 and 44 which are connected in the grid circuit.

The anode circuit of the generator is powered by a parallel circuit from the rectifier connected in a double circuit with rectifiers D_{10}-D_{11} and capacitors 4-7. Capacitor 16 in the anode circuit acts as a separating capacitor, while choke L_3 and capacitor 18 act as a block.

Regulation of the output power of the generator is accomplished by changing the voltage on the screen grid of the generator tube. The voltage obtained from the double circuit containing capacitor 4 and 6 (connected in parallel) passes through quenching resistors 29-32 to the chain of resistors connected in series (5-16) which form the stepped voltage divider. By means of switch S_3, the screen grid of the generator tube can be connected to one of the outputs of this divider. To reduce oscillations in generator power when changing the voltage of the input circuit, the voltage which reaches the divider is stabilized by a stabilitron SG1P (V_1).

Adjustable resistor 5 is intended for adjustment of the maximum value of the output power of the generator; it is set at the factory.

When switch S_3 is in the off position, reliable closing of the generator tube is achieved by applying a negative voltage to its screen grid; this voltage is obtained from a rectifier, connected by a bridge circuit made up of semiconductor diodes D_2-D_9 with filter capacitor 9.

At high frequencies, the screen grid is blocked by capacitor 17.

To produce a pulse regime for the generator, the apparatus is fitted with a modulator consisting of three 6N1P tubes (V_2-V_4). The positive half of the line voltage (at a frequency of 50 Hz) is formed by triode V_2 into a pulse which is nearly rectangular in shape. The shock positive pulses which are obtained after differentiation by means of capacitor 11 and resistor 37 are produced by a delay multivibrator with a cathode connection, linked to tube V_3. By means of switch V_4, it is possible to change the resistance of the grid leak of the right-hand triode in tube V_3. This ensures regulation of the pulse duration of the multivibrator. The regime-

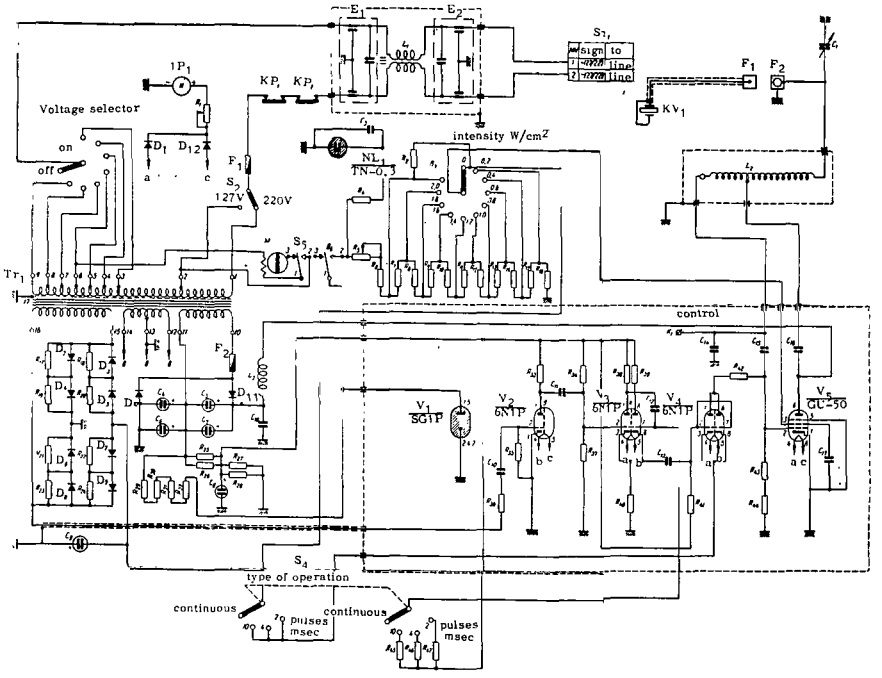


Fig. 258. Schematic Diagram of Portable Ultrasonic Apparatus for Therapeutic Purposes (UTP-1)

selector switch B_4 has four positions: three correspond to a pulse regime with one of three possible durations for the pulses, and one corresponds to a steady regime. In a pulsed regime, a negative /309
voltage is fed to the cathodes of the triodes in tube V_4 (connected in parallel) through switch S_4. The anode current of the tubes forms a voltage drop across resistors 43-44, closing the generator tube. Negative pulses from the cathode of the multivibrator pass through capacitor 13 to the grids of triodes V_4 and close them. This means that the cut-off voltage across resistors 43 and 44 drops, and a high frequency oscillation develops in the generator. The length of the high frequency pulse from the generator corresponds to the duration of the modulating pulse.

In a regime of continuous generation, switch S_4 interrupts the anode circuit of tube V_4 and the cut-off voltage in resistors 43-44 disappears completely.

The power to the anodes of tubes V_2 and V_3 comes from capacitors 4 and 6 in the double circuit through a divider made up of resistors 25-28. Additional filtration is achieved by capacitor 8.

The power for all rectifying and filament circuits is produced by means of a power transformer T_{r1}. The primary winding of the transformer is divided into sections to permit use with line voltage of 127 and 220 volts. Leads from the primary winding and switch S_1 allow compensation for changes in line voltage. A check of the line voltage can be made by using meter IP_1. The meter is connected to the filament winding of the transformer through semiconductor diodes D_1 and D_2 and regulating resistor 1 which is set at the factory.

A timer with a synchronous electric motor SD-1 (M_1) is used to shut off the generator automatically after the proper time has elapsed. It is accomplished by means of contacts 1 and 2 of microswitch S_6, thus interrupting the power supply to the screen grid of the generator tube. At the same time, the power circuit to the electric motor is interrupted and neon pilot light LN_1 goes out.

The line voltage is fed to the transformer through a shielded line filter, consisting of shielded units E_1 and E_2 and inductance coil 1. The circuit of the primary winding of the transformer contains interlocks KP_1 and KP_2, which break the connection when the top or bottom panels of the cabinet are removed; Fuse F_1 is also provided. The fuse is also used as a switch (S_2) for selecting the voltage on which the apparatus is to be used.

SPECIFICATIONS FOR SCHEMATIC DIAGRAM OF UTP-1 APPARATUS

RESISTORS

1.	Wire-wound
2.	MLT-2, 110 kΩ ±10%
4.	MLT-0.5 100 kΩ ±10%
5.	SP-2 4.7 kΩ
6.	MLT-1 1.6 kΩ ±10%
7.	MLT-1 560 Ω ±5%
8.	MLT-0.5 560 Ω ±5%
9.	MLT-0.5 680 Ω ±5%
10.	MLT-0.5 1 kΩ ±5%
11.	MLT-0.5 1.1 kΩ ±5%
12.	MLT-0.5 1.3 kΩ ±5%
13.	MLT-0.5 1.5 kΩ ±5%
14.	MLT-0.5 2.2 kΩ ±5%
15.	MLT-0.5 2.2 kΩ ±5% (adjustable)
16.	MLT-0.5 6.2 kΩ ±5% (adjustable)
17-24.	MLT-0.5 82 kΩ ±10%
25-26.	MLT-2 .2 kΩ ±10%
27-28.	MLT-2 56 kΩ ±10%
29-32.	MLT-2 1.8 kΩ ±10%
33.	MLT-2 20 kΩ ±10%
34.	MLT-1 3.3 μΩ ± 5%
35.	MLT-0.5 1.3 μΩ ±10%
36.	MLT-1 3.3 μΩ ±5%
37.	MLT-0.5 270 kΩ ±5%
38.	MLT-1 130 kΩ ±5%
39.	MLT-2 7.5 kΩ ±5%
40.	MLT-1 24 kΩ ±5%
41.	MLT-1 6.2 μΩ ±10%
42.	MLT-0.5 100 Ω ±10%
43-44.	MLT-2 1.8 kΩ ±10%
45.	MLT-1 3.3 μΩ ±5%
46.	MLT-0.5 910 kΩ ±5% (adjustable
47.	MLT-0.5 510 kΩ ±5% (adjustable)

CAPACITORS

/310

1.	Adjustable 8-24 nf
3.	KSO-2 500 volts; 560nf ±10%
4-7.	KE-2 450 volts; 20 μf
8.	KE-2 400 volts; 20 μf
9.	KE-2 300 volts; 30 μf
10.	KBG-I 400volts; 0.05 μf ±10%
11.	KSO-2 500 volts; 910 nf ±10%
12.	KSO-5 250 volts; 8200 nf ±5% (adjustable)
13.	KBG-I 400 volts; 0.05 μf ±10%
14.	KSO-5 500 volts; 6800 nf ±10%
15.	KSO-5 500 volts; 2400 nf ±10%
16.	KSO-8 1500 volts; 5600 nf ±10%
17.	KBG-I 200 volts, 0.1 μf ±10%
18.	KSO-6 1000 volts; 1000 nf ±10%

OTHER DETAILS

V_1	Tube SG1P
V_2	Tube 6N1P
V_5	Tube GU-50
Nl_1	Neon Lamp TN-0.3
Tr_1	Power Transformer
S_1	Switch
S_2	Fuse Holder
S_3-S_4	Switches
F_2	Socket
S_5-S_6	Microswitch with Roller
IP_1	Milleammeter, 0-5 ma
E_1-E_2	Protective Block 3B-2, 220 V, 10 amperes
F_1	Angular Insert
L_1	Filter Coil, 325 μk
L_2	Coil with Screen 295
L_3	High-Frequency Choke 2.5 h
KV_1	Quartz Disc
D_1	Germanium Diode D2E
D_2-D_9	Germanium Diode D7Zh
D_{10}-D_{11}	Rectifier D 1002-A
D_{12}	Germanium Diode D2E
KP_{1-2}	Interlock
K_1	Single-Pole Socket
F_1	Fuse PM 2a
F_2	Fuse PM 0.5 a
Sh_1	Plug

The general design of the apparatus is as follows. The instrument itself (Fig. 259) is mounted in a carrying case with a flat

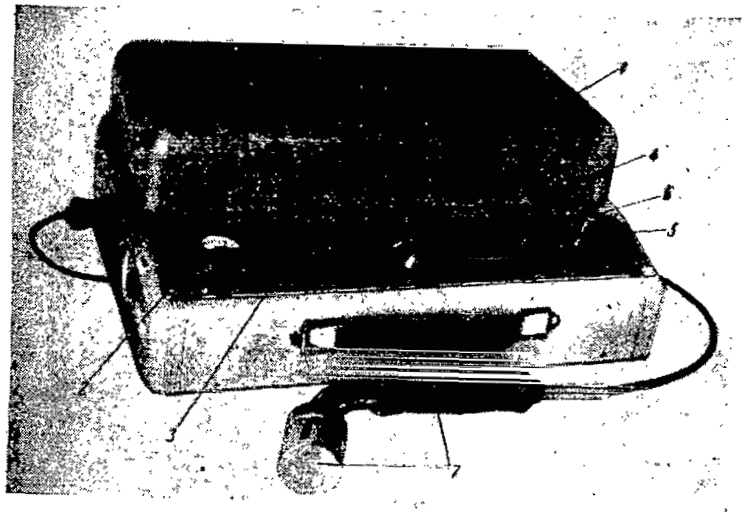
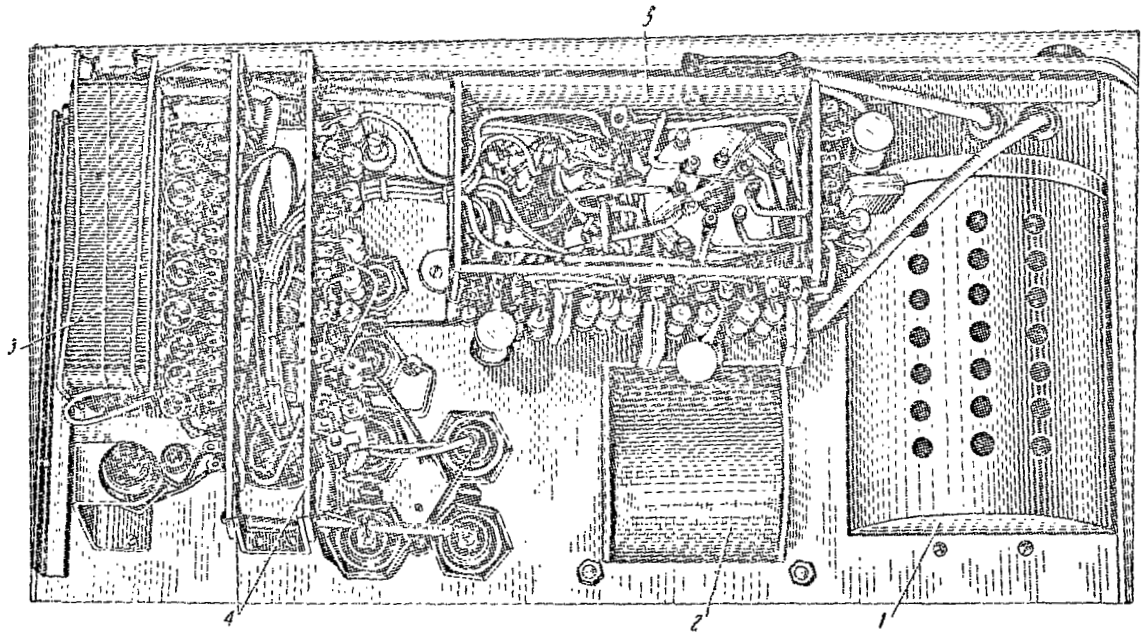


Fig. 259. General View of UTP-1 Apparatus

metal body with a movable top and bottom 1. The control panel is fitted with the following equipment: indicator 2 for the power supply voltage, knob 3 for selecting the mode of operation, knob 4 for the timer, knob 5 for adjusting the intensity, and pilot light 6. On the right-hand side of the case is a holder for the ultrasonic head 7. There is also a knob provided for setting the frequency of the generator and a connection for a high-frequency



/311

Fig. 260. UTP-1 Apparatus with Top Removed.

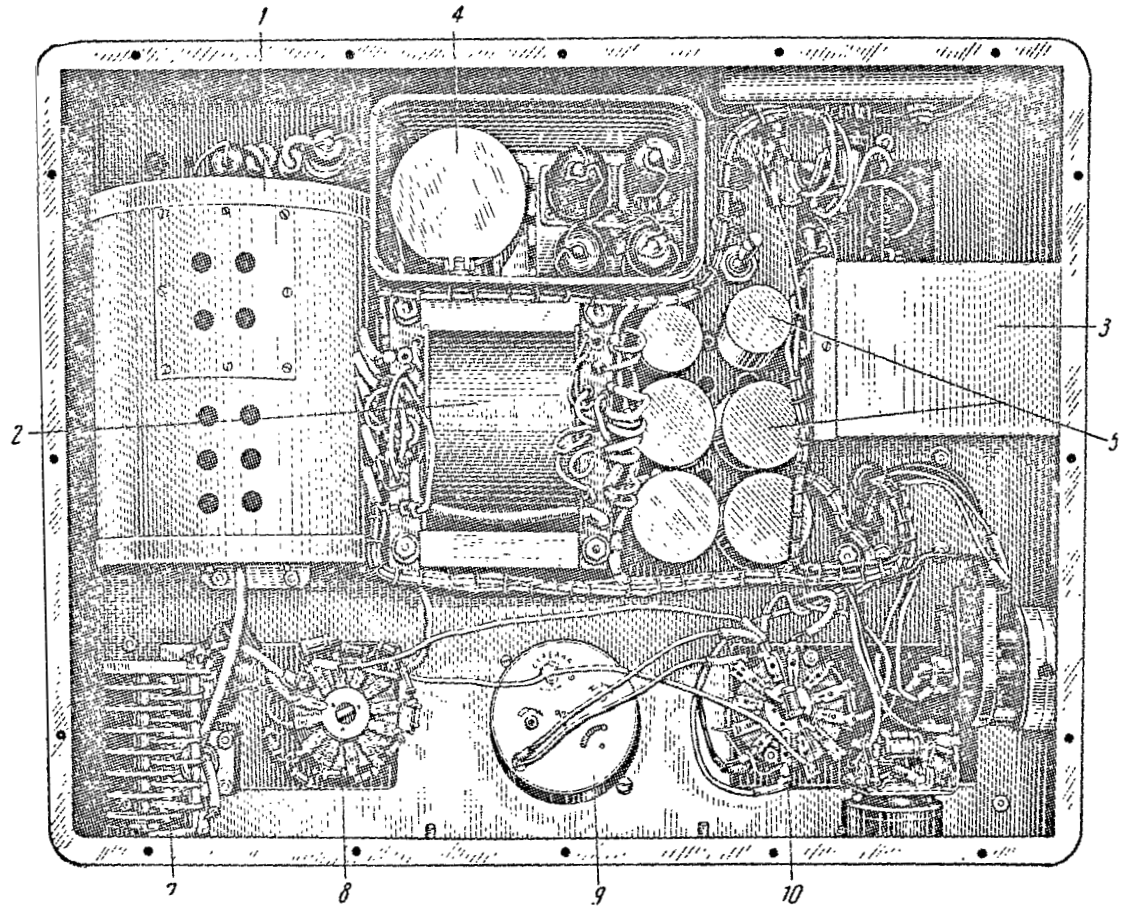


Fig. 261. UTP-1 Apparatus with Bottom Removed.

cable. On the left-hand side is the knob for adjusting the voltage /313 and the socket for plugging in the line cord.

Figure 260 shows the apparatus with the top removed. On the right-hand side, mounted on a copper screen 1, is the inductance coil of the generator. In the center is power transformer 2 and compartment 5, in which the generator and modulator tubes are located. At the left is a high-voltage rectifier 3 and beside it a perforated panel 4 with electrical parts mounted on it.

Figure 261 shows the apparatus with the bottom removed. At the left is screen 1 for the generator coil, in the center is transformer 2 and a compartment containing the generator 4 and modulator tubes; on the right are the capacitors 5 and the screen 3 for the shielded line filter. Below the control panel are the following parts: in the center is the timer 9, at the right the mode selector switch 10, at the left intensity switch 8 and a variable capacitor 7 for the generator circuit.

The ultrasonic head is made of an aluminum cup in which a resonator with a quartz disc has been installed. The opposite side of the cup is fitted with a handle through which the high-frequency cable passes. The following equipment is supplied with the apparatus:

1. Apparatus complete with tubes and ultrasonic head.
2. Line cord (1).
3. Wire for grounding, with clamp (1).
4. Spare set of vacuum tubes: GU-50 (1), 6N1P (3), SG1P (1).
5. Spare cable with plug and handle for ultrasonic radiator (1).
6. Neon bulb (1).
7. 2 ampere and 0.5 ampere fuses (1 each).
8. Technical description, instructions for use and certificate (1 each).

An ammeter for showing the power of the ultrasonic radiation (IMU-2) is supplied when requested by the customer.

Preparing the apparatus for treatment is performed as follows. After checking that the fuse-switch is set to the proper voltage and grounding the apparatus, the knob of the line voltage compensator and voltage regulator are set to the "off" position, while the knob for selecting the operational regime is in the "constant" position. If the ultrasonic head has been disconnected, the plug of the high frequency cable must be connected to the end of the cable from the head and plugged in turn into the socket on the control panel. The head is then placed in the aperture for measuring the power of the ultrasonic radiation. After plugging the line cord into the wall, the apparatus is switched on by turning the compensator knob clockwise. The knob is rotated until the needle on the voltage indicator appears on the sector on the scale of the apparatus. After the apparatus has heated up for 5-10 min, the

knob of the timer is set to 3-5 min (at which time the pilot light goes on). After setting the knob for the intensity regulator to the 1.0 position, the knob on the right-hand side of the apparatus is used to adjust the frequency of the generator so that it is in resonance with the natural frequency of the piezotransducer. The moment of resonance is determined on the basis of the maximum reading of the power meter. Then, after setting the knob on the intensity switch to the 2.0 position, meter IMU-2 (see §3) is used to determine the maximum power of the apparatus (it must be at least 8 watts).

To check the proper operation of the pulsed modulator, the apparatus must be set to the regime of pulsed operation. The /314
measured power must amount to half the power in the constant regime, if the pulse duration is 10 msec. At pulse durations of 4 msec and 2 msec, the power must be 0.2 and 0.1 of the power in the constant regime, respectively. Having checked the readings of the power meter, the knob of the timer is set to the 0 position.

This concludes the preparatory section on the operation of the apparatus. After checking it out, the desired regime of operation is set by adjusting the proper knobs. Then the duration of the treatment is set with the timer and the treatment can be performed.

At the end of the desired interval, the radiation of ultrasound is automatically interrupted and the pilot light goes out. The knob for adjusting the intensity is set to the 0 position. In the case where the next treatment will follow within 5-10 min, the apparatus need not be switched off. When all the treatments are finished, the knob for line compensation is set to the "off" position. The line cord is unplugged from the wall.

§2. PORTABLE APPARATUS FOR ULTRASONIC THERAPY (UTS-1)

The stationary apparatus for ultrasonic therapy has been developed by the VNIIMIO and is produced by the Union Factory of the EMA.

The basic data on the apparatus are the following; the frequency of the ultrasonic vibrations is 830 $\pm$ 15 kHz. In the apparatus which has been produced since 1963, the frequency of 880 kHz $\pm$ 1% is used.

The maximum ultrasonic power in the case of radiation under water is 20 watts. The maximum specific power is 2 watts/cm^2, and the radiation area is 10 cm^2. The power adjustment is continuous.

The apparatus can be used both in a constant and in a pulsed regime. The pulse duration is 2, 4 and 10 msec. The repetition frequency of the pulses is 50 Hz.

The apparatus is powered by a source of alternating current at a frequency of 50 Hz, and voltages of 127 or 220 volts, varying by +5% or -15%.

The maximum power consumption is 280 volt-amperes.

The overall dimensions of the apparatus are 500 × 300 × 320 mm. It weighs 23 kilograms.

The schematic diagram is shown in Fig. 262. The high-frequency generator for powering the quartz piezoelectric transducer is made up of a circuit with self-excitation in two generator pentodes connected in parallel; these are GU-50 tubes, V_3-V_4. The oscillator system with capacitor feedback consists of inductance coil 4, the capacitance of a high frequency cable by which the quartz transducer is connected to the generator, and capacitor 13. To increase the high frequency voltage in the converter to 2.5 kilovolts, the generator tube is connected to a portion of the windings of the coil. An exact setting of the generator to the frequency of the transducer is accomplished by means of capacitor 10, which is adjustable. Automatic bias is formed by resistors 18 and 20 which are connected to the circuit for the control grids.

The anode circuit of the generator is powered by a parallel circuit from the rectifier, arranged in a double circuit with rectifiers D_9-D_{10} and capacitors 15-16. The blocking elements in the anode circuit are the choke Dr and capacitors 8 and 9.

Resistors 21 and 23 produce additional damping in the oscillator system of the generator. This is necessary to exclude the phenomenon of "coupling" between two related resonance systems, the anode circuit of the generator and the piezoelectric transducer.

The output power of the generator can be adjusted continuously by changing the voltage on the screen grids of the generator tubes by means of potentiometer 41. The supply voltage is fed to the potentiometer from capacitor 16 in the double circuit through quenching resistors 39 and 42. /315

To reduce the oscillations in the power of the generator with changes in the line voltage, the power voltage on the screen grids is stabilized by stabilitron SG1P (V_7). At high frequencies, the grids are blocked by capacitor 11. To obtain a pulsed regime of operation for the generator, the apparatus is fitted with a modulator consisting of 6N3P (V_1) and 36N1P tubes (V_2, V_5, V_6).

The alternating voltage from winding III of power transformer Tr_1 goes across the diagonal of the phase shifting RC bridge. From the other diagonal of the bridge, the voltage runs through limiting resistors 3 and 4 to the control grids of the triodes and tubes 6N3P (V_1), which have a common load in the anode circuit.

When setting switch S_3 to the 2 msec position, one arm of the bridge is formed by capacitor 1 and resistor 34, while the other is formed by resistor 5 and capacitors 3 and 4. When switch S_3 is in the 4 msec position, the arms of the bridge are formed by capacitor 1 with resistor 34 and resistor 5 with capacitor 5. A positive pulse of corresponding duration is produced as a result of the matched phase shift in the voltage on the grids of tube V_1 in its common load resistor (R_1 and R_2). Resistors 6 and 7 serve for correction of the phase shift which is obtained.

When switch S_3 is set to the 10 msec position, the voltage on the grids in V_1 does not have a phase shift. In this case, the duration of the positive pulse in the anode circuit will be half the period of the line voltage, i.e., it will be equal to 10 msec.

Negative pulses through capacitor 2 reach the grid of the left-hand side of tube V_2, on whose cathode there is a negative voltage produces by switch S_3. The voltage is obtained from the rectifier connected in a bridge circuit made up of semiconductor diodes D_1-D_8 with filter capacitor 14. From the anode load of tube V_2 (resistor 8) a negative pulse passes through capacitor 6 to the grids of tubes V_5 and V_6 which are connected in parallel. When the apparatus is operating in a pulsed regime, a negative voltage appears on the cathodes of these tubes. The anode current of the tubes creates a voltage drop across resistors 18-20, thus blocking the generator tubes. When a negative pulse reaches the grids through capacitor 6, tubes V_5 and V_6 are blocked and the cut-off voltage across resistors 18-20 then drops. High-frequency oscillations arise in the generator and last until the modulating pulse is produced.

In a steady regime of operation, the cathode circuit of tubes V_5 and V_6 is interrupted and the pulsed cut-off voltage does not reach the grids of the generator tubes; the generator operates continuously.

To measure the intensity (specific power) of the ultrasound during the procedure, the apparatus is fitted with an electronic power indicator. In view of the quadratic relationship between the intensity of the ultrasound and the voltage on the piezotransducer, the voltmeter which measures this voltage must be graduated in volts/cm^2.

The electronic voltmeter for indicating power is incorporated in the right-hand triode of tube V_2 in a diode circuit. The high-frequency voltage, which is directly proportional to the voltage on the piezotransducer, is obtained from capacitor 13. The constant component of the anode current in the tube is measured by milliameter IP_2, connected in series with resistors 11, 12, and 24. The scale of the milliameter is graduated from 0.5 to 2.5 volts/cm^2. The adjustable resistor 12 serves to calibrate the power indicator for measuring ultrasonic power [(IMU-2); see below]. /316

When the apparatus is operating in a pulsed regime, the electronic indicator serves to show the pulse intensity.

Socket S is used to monitor the pulsed regime of operation for the apparatus during adjustment and repair.

A timer is provided for automatically shutting off the power when a set period of time for treatment has elapsed. The timer consists of a synchronous electric motor M_1, microswitches S_5-S_6, and buzzer Y_1. The design and operation of the timer is the same as in the "LUCh-2) apparatus. When the time shown on the dial has elapsed, contacts 1 and 2 of microswitch S_5 separate to break the circuit powering the screen grids of the generator tubes. At the same time, contacts 3 and 4 of this microswitch close, sending voltage to buzzer Y_1. After 20-30 sec, microswitch V_6 operates to disconnect the power from the timer and buzzer.

The apparatus is powered by a source of alternating current through power transformer Tr_1. The primary winding of the transformer is divided for connection to 127 or 220 volts. Leads from the primary winding and switch S_1 can be used to compensate for oscillations in the line voltage. Checking the power voltage is accomplished by using an instrument designated as IP_2. This device is connected to the filament winding of the transformer through semiconductor diodes D_{11}-D_{12} and resistor 40, which is adjusted at the factory.

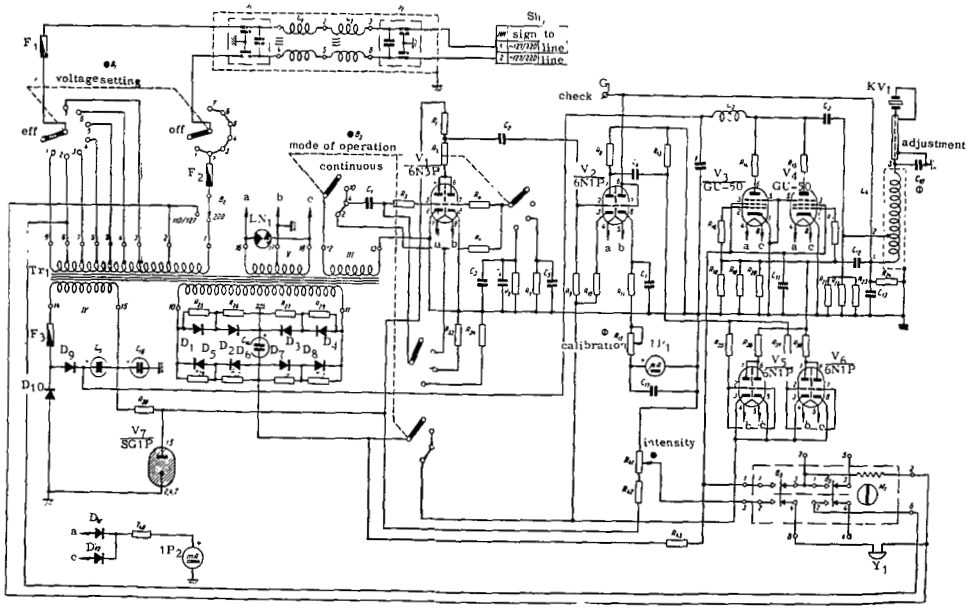
The line voltage is applied to the primary winding of the transformer through a protective filter which consists of two protective blocks E_1 and E_2 and two double high-frequency chokes L_1 and L_2. The circuit of the primary winding contains fuses F_1 and F_2. Fuse F_3 is connected to the circuit of the high-voltage winding.

Pilot light LN_1 is powered by the filament winding and lights up when the voltage is applied to the transformer.

SPECIFICATIONS FOR SCHEMATIC DIAGRAM OF UTS-1

RESISTORS

1. MLT-0.5 18 kΩ ±10%
2. MLT-0.5 82 kΩ ±10%
3. MLT-0.5 680 kΩ ±10%
4. MLT-0.5 1 μΩ ±10%
5. MLT-0.5 120 kΩ ±5%
6. MLT-0.5 560 kΩ ±5%
7. MLT-0.5 100 kΩ ±5%
8. MLT-2 22 kΩ ±10%
9. MLT-1 3.3 μΩ ±10%
10. MLT-1 1 kΩ ±10%
11. MLT-0.5 1 μΩ ±10%
12. SP-P 1 μΩ
13. MLT-1 3.3 μΩ ± 10%
14-17. MLT-1 100 Ω ±10%
18-20. MLT-2 16 kΩ ±5%
21-23. VS-5 36 kΩ ±5%
24. MLT-2 1.8 kΩ ±10%
25-32. MLT-0.5 8.2 kΩ ±10%
33. MLT-0.5 220 kΩ ± 5% (adjustable)
34. MLT-0.5 100 kΩ ±5% (adjustable)



● knob on control panel
Φ knob below slit on control panel

Fig. 262. Schematic Diagram of Stationary Apparatus for Ultrasonic Therapy (UTS-1).

RESISTORS (con't)

35-38. MLT-0.5 100 Ω ±10%
39. PEV-10 5.1 kΩ ±10%
40. Wire-wound 1300 Ω PEShOK 0.1
41. Potentiometer 25 V 8 kΩ ±10%
42. MLT-2 560 Ω ± 10%
43. MLT-0.5 1 μΩ ±10%

CAPACITORS

1. KBGI 6000 V; 0.01 μf ±10%
2. KBGI 400 V; 0.05 μf ±10%
3-5. KBGI 200 V; 0.1 μf ±10%
6. KBGI 400 V; 0.05 μf ±10%
7. MBGP 200 V; 2 μf ±10%
8. KSO-6 1000 V; 2700 nf ±10%
9. KSO-8 1500 V; 5600 nf ±10%
10. Adjustable 8-24 nf
11. KBGI 400 V; 0.05 μf ±10%
12. KSO-5 500 V; 2700 nf ±10%
13. KSO-5 500 V; 6800 nf ±10%
14. KE-2 300 V; 30 μf
15-16. KE-2 450V; 40 μf
17. KBGI 200 V; 0.05 μf ±10%

OTHER PARTS

/317

V_1	Tube 6N3P	L_1-L_2	Induction coil
V_2	Tube 6N1P	L_3	Choke, 2mh
V_3-V_4	Tube GU-50	L_4	Induction coil, 295 μh
V_5-V_6	Tube GN1P	D_1-D_8	Germanium diode D7Zh
V_7	Tube SG-1P	D_9-D_{10}	Rectifier D1001 A
LN_1	Incandescent lamp MN-16 13.5 V-0.18A	D_{11}-D_{12}	Germanium diode D2E
Tr_1	Power Transformer	M_1	Synchronous electric motor SD-2, 127 V
S_1	Switch	F_1	Fuse Pk; 2A (for 127 V,4A).
S_2	Safety Switch	F_2	Fuse PM, 2A (for 127V, 4A)
S_3	Switch	F_3	Fuse Pk; 1A
S_5-S_6	Microswitches	G_1	Single-pole socket
$1P_1$	Microammeter M494, 0-50μa	Sh_1	Plug
$1P_2$	Milliammeter M358,0-5 ma	Y_1	Buzzer, 220V
KV_1	Quartz disc,812.5 kHz	E_1-E_2	Safety block ZB-2, 220V,10A

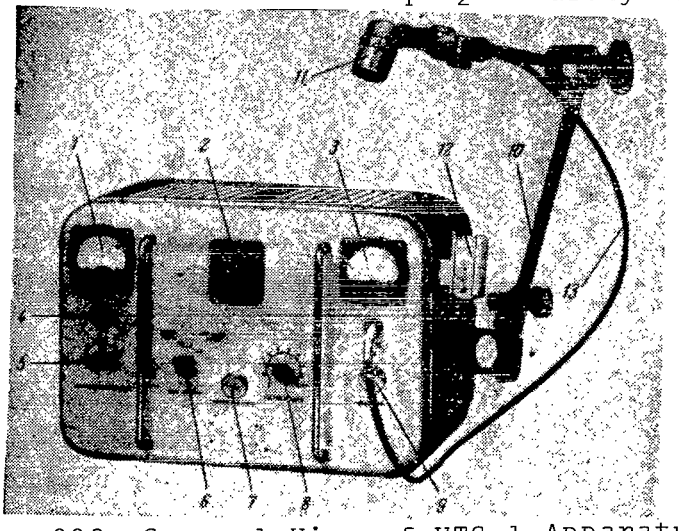


Fig. 263. General View of UTS-1 Apparatus

The following is a general description of the apparatus. The UTS-1 apparatus (Fig. 263) is mounted in a metal cabinet with a removable front, to which the chassis and the electrical components are attached. On the front, which serves as the control panel, are the following: at the top is an indicator 1 for showing the line voltage, timer 2, indicator 3 for showing the intensity of ultrasound, knob 5 for line compensation, knob 6 for selecting the operating regime, an opening 7 covered by a lid, used for manual adjustment of the power indicator, knob 8 for adjusting the intensity of the ultrasound, and an opening 9 covered by a lid for adjusting the setting of the frequency generator. Pilot light 4 is located below the indicator for the line voltage.

On the right-hand side of the chassis is a mount 10 for supporting the ultrasonic head 11. The mount is used when carrying out the treatment in a bath filled with water. The holder 12 mounted on the same side is used for holding the head in a non-operative position.

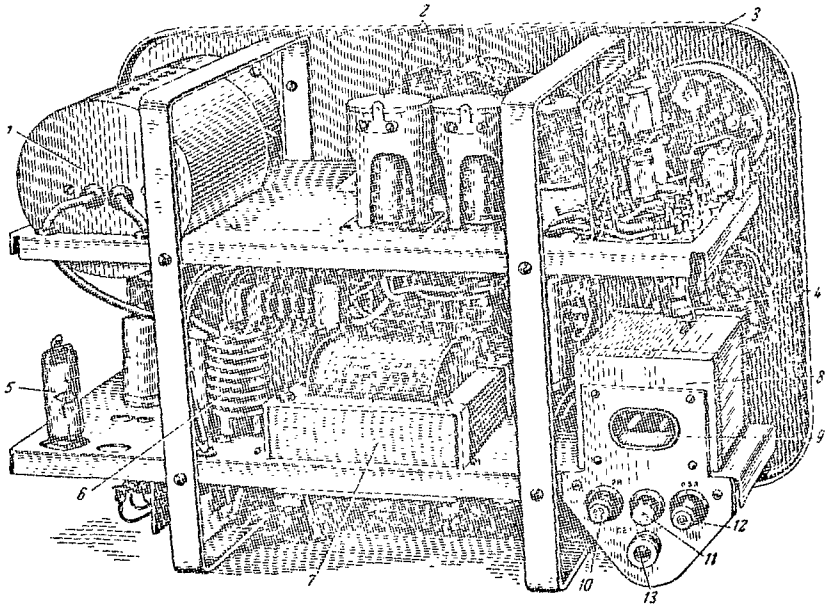


Fig. 264. Location of Parts in the UTS-1 Apparatus. /318

The ultrasonic head is an aluminum cup, to the bottom of which a quartz disc has been fastened to act as a resonator. A spring contact supplies a high frequency voltage from the generator to the disc. On the other side of the cup is a bushing fitted with a handle through which the high frequency cable 12 passes.

The appearance of the apparatus with the cabinet removed can be seen from Figure 264. The upper horizontal panel contains the induction coil for the generator with shield 1, generator tubes

2 and perforated panel 3 with the components of the modulator.

Tubes 4 of the modulator are located below the panel.

On the lower panel are the stabilitron 5, choke 6 in the anode circuit of the generator, power transformer 7, and protective filter in screen 8 with receptacle 9 for connecting the line cord. Below the line filter, on a metal panel, are the fuses 10, fuse-switch 11 for selecting 127 or 220 volts line voltage, fuse 12 for the high-voltage circuit, and terminal 13 for grounding the apparatus.

Preparing the apparatus for administering treatments is carried out as follows. After the apparatus has been grounded, the fuse-switch is set to the position corresponding to the available line voltage. When the line voltage is 220 volts, both fuses (10 and 11) must be able to withstand two amperes, while 127 volts calls for four-ampere fuses. The knob of the compensator is set to the "off" position, the knob for the intensity is set to the extreme left-hand position, and the hand of the timer is set to the "0" position.

After inserting the line cord into the wall socket, the apparatus is switched on with the knob of the compensator. The knob is rotated clockwise until the pointer of the line-voltage indicator appears in the proper sector on the instrument scale. When the apparatus is turned on, the pilot light must light up.

After 5-10 minutes warm-up time, the knob of the timer is /319
set to the desired interval for treatment. The head of the instrument is applied to the portion of the body to be treated and the regulator knob is used to adjust the intensity according to the electronic indicator of the applied power until the desired intensity of the ultrasound has been reached. It is important to remember that to avoid damaging the quartz disc, it is necessary to avoid running the head without a load, i.e., to allow it to radiate into the air.

When the time has elapsed which was designated for treatment, the high-frequency generator is switched off and an audible signal is given by the buzzer. The pointer on the electronic indicator is then set to 0. When treatment is over, the regulator knob for the intensity is set to the extreme left-hand position.

If a new treatment is not to be given, the knob of the compensator is set to the "off" position and the line cord is unplugged from the wall.

It is necessary to check the proper operation of the electronic power indicator periodically. To do this, the apparatus is turned on as described above. The head is placed in the socket of the IMU-2 instrument for measuring ultrasonic intensity. For constant operation, the knob for regulating the intensity is set to an out-

put power of 10 watts of ultrasound. The knob for "adjustment" located beneath the cover on the control panel is used to set the frequency of the generator exactly in resonance with the natural frequency of the piezotransducer. The checking of the setting is accomplished with a minimum reading of the electronic indicator of power. Having then set the IMU-2 for an output power of 20 watts, the error in the reading of the electronic indicator can then be found; it should not exceed ±20%. In the opposite case, the power indicator can be calibrated by means of a "calibrator" knob located beneath the panel.

To correct the pulse regime of operation, the IMU-2 is used to set the instrument for a constant regime of 10 watts ultrasonic power. When switching the knob for the type of operation to the positions for 10, 4 and 2 msec, the readings of the IMU-2 must be 8-12, 3-5, and 1.5-2.5 watts, respectively. The readings of the electronic power indicator in response to changes in the operating regime are practically constant.

§3. INSTRUMENT FOR MEASURING ULTRASONIC POWER (IMU-2)

An ultrasonic wave striking an obstacle in its path produces pressure whose magnitude is directly proportional to the power of the ultrasound and can therefore serve as a method of indirect measurement.

The instrument for measuring ultrasonic power (IMU-2) was developed by VNIIMIO and is produced by the Union Factory of the EMA.

The basic features of the apparatus are as follows: measurement range, -0.5 to +22 watts; maximum measurement error, ± (0.25 watts + 5% of the measured value); frequency of ultrasonic vibrations 400 + 3000 kHz; temperature range from +10 to +35°. Overall measurements: 245 × 166 × 145 mm; weight, 5.5 kilograms.

A general view of the IMU-2 instrument for measuring ultrasonic power is shown in Fig. 265, while a view of the instrument in cross section appears in Fig. 266.

The instrument is a sensitive measuring device located in a hermetically sealed chamber 1 filled with doubly distilled water. The upper part of the chamber contains an opening 2, covered by a thin polyethylene cover 3. When taking measurements, the head of the ultrasonic therapeutic apparatus is inserted into this opening. The actual measuring device is a highly sensitive beam balance. At one end of the beam 11 is a sensor in the form of two reflecting discs 13 connected at an angle. Below the discs is a hollow plastic float 12. The movement of the sensor under the influence of the ultrasonic waves, transmitted by flat springs 5 and 8, causes lengthening or shortening of the thin metal chain 4, to the center of which is fastened a pointer 10. Before carrying out a measure- /320

ment, the pointer is set to 0 by means of knob 6. The reading of the ultrasonic power is obtained by examining the deflection of the needle along the scale 9; the latter is graduated in watts.

In using this instrument, it is necessary to be very careful to avoid shocks and vibration; freezing of the water will put the apparatus out of commission, so that it must be protected from frost.

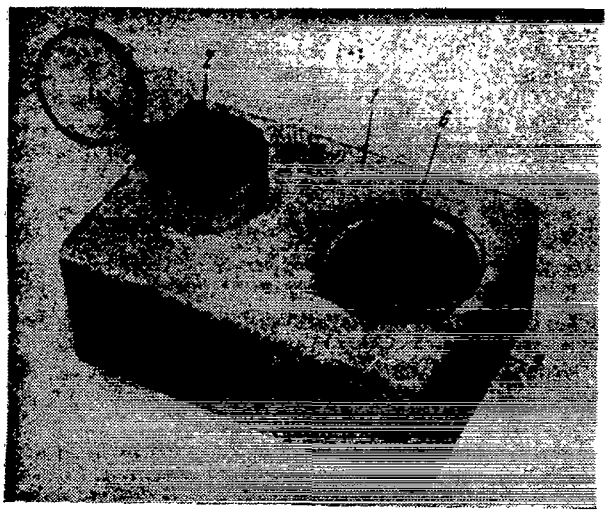


Fig. 265. General View of Instrument for Measuring Ultrasonic Power

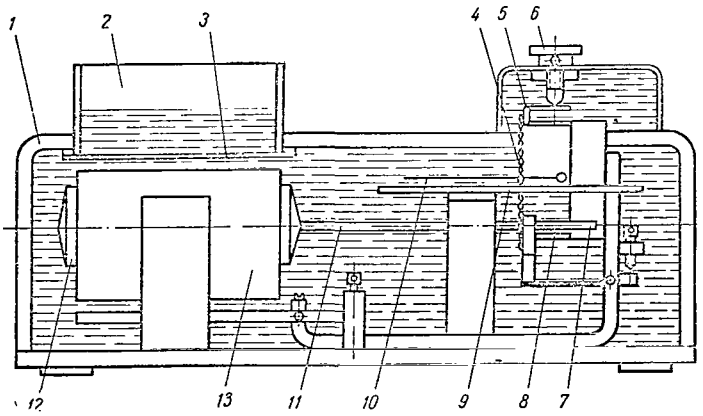


Fig. 266. Diagram of Mechanism for Measuring Ultrasonic Power.

CHAPTER VI

ORGANIZATION AND OPERATION OF ELECTRICAL PHOTOTHERAPEUTIC DEPARTMENTS

PART 1

ORGANIZATION OF AN ELECTRICAL PHOTOTHERAPEUTIC DEPARTMENT

The organization of therapeutic assistance by means of physical /321
methods in joint therapeutic and prophylactic institutions may have different structures depending on the scope of the work performed.

In the smallest institutions, special physical methods are employed, for which corresponding equipment is used.

In institutions which handle an average volume of work, there is a separate structural unit, the department of physical therapy, which is equipped with the basic electrical phototherapeutic apparatus. In the department (or in the division), there is also a certain amount of portable equipment used for procedures in physical therapy, performed directly at the patient's bedside (in wards, bandaging rooms, etc.).

Finally, in large institutions there is a department of physical therapy which consists of several specialized departments. In the clinical divisions, branches are organized which are supplied with equipment depending on the type of division. The department of physical therapy must have sufficient space and be bright, dry and warm (since a number of procedures demand exposure of appropriate parts of the body). It must also be equipped, like every therapeutic department, with a supply of hot and cold water. Installation of intake and exhaust ventilation is obligatory.

Departments (especially those for phototherapy and those using currents of constant and low-frequency) are equipped with isolation wards and rooms. In an electrotherapeutic department where high-frequency currents are employed for procedures of inductothermy, UHF therapy, and microwave therapy, and it is not necessary to expose the appropriate parts of the body completely, such areas may be open, using only screens or curtains to separate individuals.

The floor in these departments must be made of a thin non-conducting material such as parquet or painted wood, or it may be covered with linoleum.

Pipes from the central heating system, water or sewage pipes located on the premises, as well as any grounded metal objects, must be shielded by wooden sheathing and covered with oil paint.

The necessary area of the location is determined on the basis of the apparatus to be located in it. On the average, it is considered that the necessary floor space required for one stationary electric phototherapeutic apparatus, (with a couch on which the procedure is carried out) must be at least 6 m square.

The department is equipped with couches or special furniture; /322
it must be remembered that the furniture used for performing high-frequency therapy (especially inductothermy and UHF therapy) must not have metal parts.

The arrangement of the apparatus in the department must ensure both comfort for the patient and easy access to the equipment for attendants. Since the cabinet and supports of a great many instruments must be grounded, and grounded objects must not be located within the range of the patient, it is recommended that the apparatus be placed whenever possible behind the head of the pillow of the couch on which the procedure is being carried out. Rearranging the equipment without the permission of the director of the department is not allowed. When solving problems regarding rearrangement of equipment, it is also necessary to consider the arrangement of available wall sockets.

Some of the high-frequency apparatus can only be used in a shielded chamber. This chamber is erected in the department and screened by decorative curtains.

Each electronic and phototherapeutic department must have its own electrical supply, using copper wire with a minimum cross section of 6 mm^2, if a larger cross section is not dictated on the basis of calculations. For distributing loads by phases, wires are used which carry 380/220 or 220/127 volts in 4-wire cables. It is forbidden to conduct other loads to these wires. Inside the department, at a height of 1.6 m above the floor, there is a master switchboard with a main switch handling 60-100 amperes. A voltmeter with 250 volts capacity and a phase switch are mounted on the panel.

"E-27" fuses, with the number of groups corresponding to the number of instruments that have been installed (sterilizers and electric scales are considered instruments) are mounted on the master switchboard.

For connecting the instruments in the rooms, wall sockets of

insulating material are mounted 1.5 m above the floor. A two-pole knife switch or other type of switch which can handle 25 amperes is also mounted on the switchboard, along with one or two porcelain sockets and two terminals. The board is also fitted with a grounding clamp. The lines from the switchboardare made of copper wire with a cross section of at least 2.5 mm^2.

All of the actuating devices are mounted in protective housings.

PART 2

ACCIDENT PREVENTION AND WORK RULES IN ELECTRIC PHOTOTHERAPEUTIC DEPARTMENTS

The effect of electricity on the organism depends primarily on the form of the electrical process (for example, either a current or a electrical or magnetic field effects the organism); it also depends on the physical characteristics and especially the intensity of its effect (current intensity, field intensity, etc.). The degree of the harmful effect of electricity also depends on the conditions under which it acts on the organism (for example, the path followed by the current through the body), on the state of the organism, and even on the psychic factor of unexpected trauma.

The subject of this section is to study the methods which can ensure complete safety against injury from electricity under the conditions of working in a phototherapeutic or electrotherapeutic department, both from the standpoint of the patients who are receiving treatment and from that of the personnel who are working with the electrical apparatus.

Safety precautions and work rules which ensure safety with /323
respect to the possibility of electric shock both for patients and for the personnel of the electrical and phototherapeutic departments are set forth in the book "Rules for Safety and Sanitation for Work in Physical Therapy Departments", issued in 1959 by the Assistant to the Minister of Safety of the USSR and the Presidium of the Central Committee of the Trade Union of Medical Workers. These instructions must be placed in every physical therapy department and division, and must be brought to the attention of every worker, beginning with the nurses and orderlies and ending with the director of the department.

The principal guarantee that the patient will not be harmed during treatment instead of being cured is the observation of all rules for carrying out the procedures, especially the correct operating condition of the apparatus. This explains why there must be a constant careful supervision of the apparatus by the personnel working on it,careful observation on the part of the nurses performing the treatment, as well as strict adherance of all personnel to the rules for the use of the apparatus, the techniques for carrying out the treatment, and safety procedures.

In this regard, the instructions mentioned above for the techniques of safe operation stress the following:

Only doctors and nurses who have received special training in physical therapy should be allowed to use these instruments to treat patients.

The medical treatment must be carried out only with apparatus which has been completely checked out according to the description provided with it; the repair shop must have the schematic diagram and technical certificate from the factory. Apparatus which is returned from the repair shop must have a certificate issued by the actual worker who is responsible for keeping the schematic electrical and wiring diagrams for the repaired apparatus and for ensuring that the apparatus satisfies all the medical and technical requirements.

Only persons who have received suitable training and have qualofication certificates should be allowed to service the electrical and phototherapeutic apparatus and to repair it.

As we have seen above, modern electrical phototherapeutic apparatus uses complex vacuum tube circuitry to a large extent; this calls for a very high degree of skill on the part of the personnel who are servicing the apparatus. Insufficiently qualified personnel must not be allowed to work on this apparatus, since lack of sufficient experience of knowledge in these personnel may lead to misalignment or even damage to the equipment. However, even a high degree of experience in radio technology without special knowledge regarding the special details of use of a particular piece of electrical apparatus for therapeutic purposes can lead to incorrect adjustment of the apparatus and damage to its functional capacity.

Unfamiliarity with the method of administering procedures and with the special requirements of safety precautions may lead, for example, to the installation of an autotransformer in the very simple phase apparatus for galvanization; should treatment be given with such an apparatus when grounded objects are within the patient's reach, there is danger of a shock (through grounding), with the patient being exposed to low frequency alternating current and all the consequences that can follow from it. From even this small example, it is clear that it is very necessary to learn carefully and scrupulously observe all the rules for safety, as well as for physical therapy, as well as to study carefully the physical principles of the different methods of treatment and the methods of carrying out the particular procedures.

A periodic check of the apparatus must be made no less than once a week; the results of the check to certify the correct operation of the apparatus must be made by a physical therapist and entered in a special log kept in the department. The personnel /324

(nurses) in the department must make entries in the same log regarding any peculiar or incorrect operation of the devices which they may have noticed.

The greatest danger to the organism comes from alternating current at a frequency of 50 amperes, especially at voltages of 220 and more, which are found in lighting and industrial circuits as well as in the power supplies of many instruments. Damage from alternating current may occur not only in the case when a person simultaneously touches two sides of the circuit or the poles or aratures which are subjected to the voltage (or touches some other current-carrying object which is connected to these wires or fields), but also in the case when a person touches one of these and is grounded at the same time. Such conditions can occur if the person is standing on earth, brick, cement, etc. or some similar material or is in contact with a grounded metal object such as a water pipe, gas main, sewer pipe, metal support, beam, hand rail, etc.

A person can come in contact with AC voltage if he touches the chassis of a faulty apparatus in which some part or wire carrying a voltage is touching the cabinet. To prevent this, the chassis of all apparatus should be carefully grounded.

If all of these rules for safe operation of the apparatus are followed, the patient will not come in contact with the AC voltage. However, if these rules are not followed, this possibility cannot be excluded.

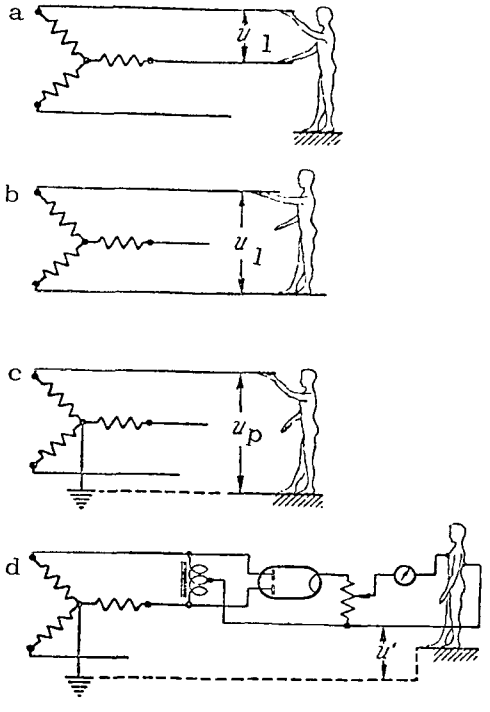


Fig. 267 shows some cases in which a person may come in contact with line voltage: a and b show a person being subjected to the line voltage U_1 in the system by coming directly in contact with two wires; c shows a person touching one wire, with the other wire grounded and the person standing on a place where he, himself, is grounded (or touches a grounded object) so that he is subjected to the phase voltage U_p in the line. Finally, d shows a person receiving phase voltage U or somewhat less during treatment such as galvanization,

Fig. 267. Schematic Diagram of Various Cases in which a Person Can Come in Contact with AC Voltage.

when he is simultaneously grounded or is in contact with a grounded /325
object, in the case where a rectifier has been used in the galvanization apparatus which is directly connected to the line through an autotransformer.

The nature of the damage produced by electrical current depends to a considerable degree upon the magnitude of the current which passes through the organism. As a rule, the latter is governed both by the voltage and the resistance of the portion of the organism subjected to the current. Therefore the magnitude of the current depends to a large extent on the area which is either in direct or indirect contact (for example, the exposed portion of the body or clothing, whether it is dry or wet), and especially on the state of the skin at the point where the current enters and leaves.

In connection with what has been said above regarding the significance of the state of the organism for the effect of the action of the current, it is difficult to determine the magnitude of the current which is dangerous for the organism. Nevertheless, it should be stated that the value of the alternating current at industrial frequency, which exceeds 15-20 ma, can have dangerous consequences for the organism.

It should be mentioned that "grounding" itself is not dangerous, but it does increase the danger of accidental contact with current-carrying parts which are subject to a voltage to a considerable degree.

Therefore, technical safety precautions must involve attention to two types of measures: those which are intended to reduce the possibility of contact with current-carrying parts of the apparatus and armatures, and those which prevent the possibility of grounding.

The wire used in connecting the apparatus to the line must be made of flexible wire sealed in rubber; if this is not available, a wire run through a rubber tube can be used.

Wires which carry high voltage current to the patient (as in the franklinization apparatus, for example) or high frequencies (such as the apparatus for general and local d'arsonvalization, diathermy or UHF therapy) must also be provided with high-frequency and high-voltage insulation. Wires with dried-out insulation should not be used. It is important that all of the wires, especially those used for connecting the electrodes for diathermy, and all of the insulation must be carefully checked before carrying out these medical treatments. During the treatment itself, the wires should not be allowed to touch the patient's body.

Metal cabinets and supports for electrical and phototherapeutic apparatus, including portable ones, should be cardfully grounded by connecting them to a special apparatus for grounding, which must be built according to the proper electrotechnical specifications.

In departments which have already been set up, where the installation of such a circuit would be difficult, the apparatus can be grounded by connecting it to water pipes, under the condition that the water pipes are filled with water and connected to the city main, and that the pipes are connected to a special link for carrying the electrical current past the water meter.

Grounding should be carried out with wire which has considerable mechanical strength (a cross section of at least 2.5 mm^2 and no intermediate connections).

The grounded cabinets and supports of the apparatus, as well as any other grounded apparatus, must be placed beyond the reach of the patient or should be covered with insulating covers over all exposed surfaces and up to a height which will prevent the patient and personnel from touching them during the treatment. /326

In setting up the four-chambered bath, the faucets, pipes, and other metal parts of the water supply and drains must be located beyond the patient's reach.

Grounded (i.e., cement, ceramic, etc.) floors beneath all installations must be covered to a distance of at least 1 m in all directions by electrical insulating and waterproofed materials (linoleum, rubber matting, etc.).

The baths are filled with water by using rubber hoses. The water can also be drained from the baths by using rubber tubing and a water pump operated by the faucet.

In systems where the water is drained from the bath into a drainage pan located beneath the apparatus, the top of the pan must be no less than 25-30 cm below the bottom of the drainage tube. Stoppers in the bath must be fixed in place and those in the bottoms of the bath must be held in place by rubber fasteners which will prevent the stoppers from possibly being knocked out. In addition, it is also necessary to check the state of these stoppers, since no water must be allowed to leak out through them. Filling the bath with water and letting it out must always be done with the apparatus switched off.

When carrying out electrotherapeutic treatments outside the department of physical therapy (in the bandaging room, operating room, ward, etc.), when the patients are located on stretchers or metal tables or beds, it is necessary to exclude the possibility of contact with the latter. This means that the metal table must be covered with cloth, and 3-4 layers of rubber coated cloth, as well as sheets of such size that their edges cover all sides of the table. A metal bed must be covered with a cloth or cotton mattress and a sheet which covers all of the springs and frame of the bed; the head and foot of the bed must be carefully covered with cloth also. If the floor in these places is made of brick,

it must be covered by an insulating material (rubber matting) measuring no less than 1 m^2.

For steralizing the instruments, coverings, and other parts, it is necessary to use containers, sterilizers, or heaters with enclosed heating coils. Heating water on a hot plate with exposed coils in the vessels mentioned above is not permitted. High voltage (DC or AC) at low frequency flows through the electrical circuitry of a number of devices. This means that such apparatus must be mounted in cabinets whose removable panels or doors are fitted with protective devices (interlocks) which interrupt the current when the doors are opened or removed. The rules for safety forbid the use of apparatus for d'arsonvalization, diathermy, UHF therapy, inducto thermy, franklinization, etc. which is not fitted with electrical interlocks on the doors (removable panels) and also forbid the use of these devices if the interlocks are inoperative. The department personnel are forbidden to short-circuit the contacts of the interlocks or the use of cheater cords.

Adjustment of the apparatus or the repair of damage must be carried out with the power switch off. In case it should be necessary to adjust an apparatus operating at high voltage, it must be done in accordance with the proper special rules for electrical safety: a second person should be in the vicinity who has been instructed in the rules of safety and for rendering first aid in case of electric shock; the workers must stand on a rubber mat and must wear rubber gloves; all the procedures which are related to adjusting the apparatus must be carried out with one hand and with a tool having an insulated handle, etc.

Particular care must be taken when adjusting the UDL-350, /327
DKV-1 and DKV-2 when they are plugged in, since shutting off the high voltage effects only the minus side and therefore shutting off the high voltage means that some parts of the circuit will still be at high voltage relative to the cabinet or to the grounded parts of the circuit.

We can finish our discussion of the safety procedures involved in electrotherapeutic departments by mentioning the measures which will reduce these dangerous effects on the service personnel as far as the apparatus used for electrotherapy with UHF fields is concerned.

The use of UHF generators with an output power greater than 200 watts involves danger for the personnel operating it. This danger is increased in those cases when the energy in the therapeutic circuit is only partially absorbed by the patient, with the remaining portion being radiated into space. This occurs in the case of large gaps between the electrodes and also in the case when only one electrode is used.

A complete absence of any effect of UHF generators on the personnel can be achieved only by building a special shielded and

grounded chamber in which the apparatus and patients must be located when treatment is being given. If the shielded chamber is lacking, it is recommended that the UHF generator be located in the department so that the place where the personnel stand when operating it is located at least 3 m from the generator.

Particular danger to the operating personnel comes from the prolonged effects of the direct flux from decimeter and centimeter waves. In this regard, the personnel are exposed to directional radiation from apparatus used for microwaves therapy. To shield the personnel located near the place where such radiational therapy is being administered, it is recommended that protective screens be used, in the form of sheets covered with a thick metal coating or a special cotton cloth containing thin copper wires. Cloth of this sort can also be used for outfitting the changer in which the treatment is performed.

In working in the phototherapeutic department, all of the safety rules outlined above must be observed. In addition, it is also necessary to observe precautions to protect against radiation.

It is dangerous to look at heaters with unprotected eyes. To carry out treatment, the eyes of the nurses (or technicians who are checking the operation of the lamp) must be covered with goggles with dark lenses. The eyes of the patient must also be covered by protective goggles.

The medical treatment must not be given when wearing clothing with short sleeves. The part of the body of the patient which is not being subjected to radiation must be covered by cloth.

All incandesent lamps (except during treatment) must be aimed with the reflector toward the floor. Openings in the reflectors must be covered; open reflectors must be covered with thick curtains made of dark cloth.

In working with lamps with short-wave or ultraviolet radiation, it is necessary to shield the eyes with goggles containing ordinary glass.

It is also recommended that personnel avoid looking at the /328
filaments of lamps used for infrared radiation for any prolonged period of time, and that the eyes be protected against the effects of infrared rays.

PART 3

MAINTENANCE AND REPAIR OF APPARATUS

Correct operation and working conditions of the apparatus are ensured by systematic checks and preventive maintenance.

According to the book "Rules for Safety and Sanitation for

Work in Physical Therapy Departments", at least once a week the apparatus must be checked by a physical therapist and the results recorded in a special log. The following should be checked: (1) the proper operation of the apparatus and the possibility of using it for treatment; (2) prompt repair of any parts of the apparatus or accessories; very frequently, the parts of the apparatus (especially the wires and electrodes) will gradually be damaged due to erosion and inaccurate or incorrect usage. Such damage can be repaired by careful maintenance and replacement.

In carrying out preventive maintenance of the apparatus, it is necessary first to be sure that it is cleaned both inside and out. Dust which has penetrated must be removed by brush or vacuum cleaner. In no case should dust be wiped off capacitors, coils, insulator panels, or contacts of the apparatus by using a moist cloth. The external surface can be dusted and the rubber insulation wiped with a clean and slightly moistened cloth.

In checking out the apparatus, special attention must be paid to the condition of the adjustment knobs and various movable parts, as well as the meters (correct setting of the pointers to zero), vacuum tubes, and other parts which are used frequently. In checking out the parts of the electrical circuit of the apparatus, it is necessary to pay particular aattention to the state of the contacts and connections between the various parts and wires, etc. In case of a poor contact at places where the wires join or other elements of the circuit are connected, there may be a burning of the adjacent surfaces, leading to disruption of normal operation of the apparatus and eventually to breakdown.

Special attention should be given to checking the wires which run from the wall to the apparatus and from the apparatus to the patient. Any break in the insulation which is noticed should immediately be wrapped with friction tape or covered by rubber tubing. Wires which have dried-out, cracked insulation must be replaced immediately by new ones.

The electrodes, especially the flexible lead ones used for galvinization and diathermy, must also be carefully checked. The electrodes must be checked carefully at intervals to ensure that their surfaces (which become oxidized and dirty with use) are clean. It is necessary to remove the coating which accumulates on them and then flatten them with a steel roller (or a smooth glass cylinder) on a steel or glass plate. It is also necessary to check carefully the wires leading to the electrodes. Worn-out or damaged electrode strips must be replaced by new ones at once.

All of the electromedical apparatus must be kept in a dry /329
place, both during use and when sotred. When moving the apparatus from a warm location to a cold one and vice versa, the apparatus should only be turned on ofter it has reached room temperature. The apparatus should be moved or carried about carefully without dropping it or striking it against objects; if it is necessary to

transport it for a considerable distance,especially in the case of stationary apparatus, the vacuum tubes should be removed and shipped separately.

When the apparatus is received from the factory or from the shop, attention should be paid to the condition of the packing material; when the material is unpacked, the contents should be checked against the packing list and any discrepancies or damage should be remedied at once.

The material should be wiped with a dry cloth after being unpacked and carefully checked over. It can then be fitted out with required parts, such as vacuum tubes.

Before using the apparatus, the instructions which are provided with it should be read carefully and a check made to see that all the parts have been shipped.

Before plugging the apparatus into the wall for the first time, the connections to the primary winding of the power transformer should be checked to be sure that it is set for the line voltage (127-220 volts). As a rule, the factory ships the apparatus set for 220 volts, but it should be checked anyway.

In the case of apparatus which contains thyratrons and gas-filled rectifier tubes in the circuit (KED, UDL-350, DKV-1, etc.) it is necessary to allow the tubes to heat up for 45 minutes before turning on the high voltage for the first time. When turning on any apparatus for the first time (even one which does not contain gas-filled rectifiers), it is necessary to wait 3-5 minutes after turning it on before connecting the high voltage; this is necessary in order to allow the tubes to warm up properly.

Special instructions for setting-up, using and repairing specific instruments are provided in the instructions shipped with the apparatus, which must be carefully kept in the department or division. It should be available when necessary. In this chapter, we can make a few general remarks which might be useful for beginners in this field. Further detailed remarks regarding the avoidance of danger in special types of apparatus have already been mentioned in the second edition of this book (1960). Repairing the apparatus usually proceeds in three steps: (a) determining the nature of the problem, (b) finding the damage, (c) testing the operation of the instrument after it is repaired.

Usually the local repair shop has various circuit components (switches, selectors, potentiometers, etc.) as well as low-power transformers (for portable apparatus) on hand. The vacuum tubes, capacitors, and resistors as a rule are not repaired but replaced by new ones.

In replacing damaged parts by new ones, it is necessary to

follow the technical data provided in the description of the apparatus or in the description of the schematic diagram; this means that depending on the operating conditions of a given part in the apparatus, its technical data must be given with a certain degree of accuracy. For example, the specifications for the schematic diagrams show that a given resistor or capacitor has a certain tolerance, beginning with ±5% and ending with ± 20%.

The parts which are included in oscillator circuits and the /330
circuits of measuring devices must be replaced in strict accordance with specifications in the data.

Bias resistors, as well as quenching resistors located in the electrode circuits of tubes show considerable variation from the nominal value. This deviation, however, need not cause much disturbance in the operating regime of the tube, as mentioned under the description of the apparatus. In some cases, such a deviation from specifications may be temporary, for example, when certain parts are not available. Considerable deviations from the nominal values are permissible for the blocking elements in the circuit (chokes, capacitors, limiting resistors).

A general rule for repairing any electrical circuit is to check it by units or blocks. Regardless of the design of the apparatus, the following order should be followed:

1. Determining whether there is a power supply voltage applied to the input socket and then to the primary winding of the power transformer.

2. Checking for the presence of currents to the filaments of the vacuum tubes.

3. Checking for the presence of a voltage on the step-up windings of the transformer; in apparatus which is equipped with a rectifier, one should check for voltage at the output, as well as the presence of this voltage at various blocks of the circuit. This can be carried out in practice by measuring the voltage on the electrodes of the tubes.

4. When power is available in all sections of the apparatus it is necessary to proceed to a detailed testing of each of the operations of each of the blocks separately. This check can also be carried out in a certain sequence, beginning with the first section and proceeding to the last. For example, in complex apparatus with a stabilized frequency (UDL, DKV) the check of the operation of the apparatus can be followed beginning with the master generator, proceeding to the intermediate amplifier and from the latter to the output amplifier.

5. The check of the operation of any circuit must always be done directly at the output (circuit) of this block. For example,

in the UDL and DKV apparatus this is done by checking for the presence of a high frequency oscillation in the anode oscillator circuit and checking for its proper function. In case such a check gives negative results, one must find out the reason for the failure of the unit to operate, i.e., a detailed check of operation and the condition of all individual parts must be made.

Let us now proceed to some particular tests of parts.

The majority of apparatus have pilot lights on the control panel which indicate the presence of a high voltage in the power transformer. When this pilot light goes out and the apparatus is not switched on, any one of the following may be the problem: (a) Lack of voltage in the wall socket (some defect in the wire or in the plugs) or a break in the lead; (b) A fuse in the apparatus may have blown out so that no current reaches the primary windings of the power transformer; (c) Contact may be broken in the electric interlock which protects the removable sides of the cabinet (in cases where they are installed, or it may be in the voltage compensator switch, in the sockets for mounting the fuses, in the line switch, etc; (d) There may be a faulty contact in the pilot light socket itself, or the lamp may have burned out. In this case, there are usually other signs that the apparatus is working (for example, the meter pointers are operating, showing the supply voltage, there is a low hum from the transformer, the filaments of the tubes are lit, etc.), which readily show the source of the trouble. /331

Poor contact can be revealed by using a tester with a scale for showing resistance.

If an apparatus fitted with a voltmeter for measuring the power voltage (especially in circuits with voltage compensation) has a pilot light which lights up, but the indicator needle shows a reading much less than the usual value and cannot be brought up to the red line by moving the voltage compensator adjustment, it may be assumed that there is some damage to the rectifier in the measuring instrument. To avoid this, it is necessary to replace the rectifier by a new one and check the calibration of the instrument, and also to make control marking on the scale.

The next source of possible trouble is the power transformer itself. There may be some contact between the windings and the cabinet, or some of the windings may have become short-circuited. In this case, when the apparatus is plugged in the transformer hums loudly and the fuse burns out. We can see that this sort of behavior on the part of the transformer can also take place if there is a short circuit in the secondary winding. To find out where the trouble is, we can disconnect from the transformer the wires which run from the secondary winding and then plug the transformer into the line. If the problem is beyond the transformer it will then operate normally.

It is also possible to have a partial break in the wire so that short circuits are formed in them. In this case, the transformer will operate with an overload and be overheated; after a while there will be danger of the insulating coating melting; such damage to the windings of the transformer usually puts the apparatus out of commission, but in some cases it may not interfere with it.

The cause of damage to the transformer windings may be the penetration of moisture ("wetting" of the windings) or some problem in operation of the apparatus. This kind of a problem can arise for example, when the windings are subjected to an overload in connection with a short circuit in the apparatus, or some defect in the insulation between the layers of the windings due to a sudded increase in voltage.

The following group of possible troubles applies to the generator portion of the apparatus. In this case, to detect the problems and repair them, it is necessary to be familiar with the details of the circuit, although a few general remarks will apply. The elements which are most likely to suffer damage are the vacuum tubes, since their service life is much shorter than that of the other parts of the apparatus; therefore, under normal conditions they must be removed periodically and replaced by new ones.

The breakdown of a tube can affect the operation of the apparatus in different ways, but in the final analysis it involves either a complete absence or insufficiency of power at the output of the apparatus.

The main reasons for failure of vacuum tubes are (a) burning out or breaking of the filament, (b) breakage of the electrodes, (c) loss of emmission, (d) loss of vacuum.

However, before solving the problems of the failure of the tube to operate, it is to be sure that there is no problem causing difficulty in operation of the apparatus as a result of insufficiently good contact between the terminals of the tubes and the socket. The socket contact on the panels can easily move away from the pins on the bottom of the tubes, thus breaking the contact: therefore, the first thing to do in checking the operation of the apparatus in cases where low-power tubes are used is to check to be sure that the contact at the base of the tubes is in order. This can be done by pulling the tubes out of the panel, checking and adjusting the contacts on the panel, and reinserting the lamp into the socket, checking to be sure it is in the proper position. Burnt-out filaments can be detected first of all by failure of the tubes to warm up. In order to be absolutely sure it is the filament which has burnt out, a tester must be used. /332

The most general device for checking defective tubes is the sequential replacement of tubes in the apparatus by new ones (spares). Checking the operation of the apparatus by replacing one tube at a

time reveals the defect in the old tubes. If there is no spare supply of tubes, but the tubes light up yet do not work properly, it is necessary to check the operating regime, especially the voltage and current in the anode circuit.

If there is a normal voltage on the electrodes, and the anode current is much greater than the nominal value, changing only slightly when the bias is disconnected, it indicates that the vacuum in the tube has been lost. In tubes with glass envelopes, loss of vacuum ("gassiness") appears in the form of a uniform violet coloration.

A drop in the value of the anode current relative to the nominal value (with normal anode and grid voltages) is usually related to a drop in the tube emission ("aging").

In conclusion, we would like to add several remarks regarding the recommended procedure to be followed in the repair shop of the physical therapy department.

Preventive maintenance of the apparatus, as well as any minor adjustments which may be involved, require that the shop be equipped with the usual set of tools and materials (combination cutting and twisting pliers, nippers, a supply of screw drivers, knives for cutting insulation, a soldering iron, solder and rosin flux, friction tape, rubber tubing, as well as a supply of spare parts for fuses, insulated wire, etc.) As far as measuring instruments are concerned, there should be a universal tester or vacuum voltmeter, as well as a neon bulb with an insulated handle for testing for high-frequency oscillations.

However, the qualified technician should have a more complete set of tools for repairing the apparatus that he encounters in the course of his work, enabling him to reduce the amount of time the apparatus spends on the bench. To do this, it is necessary first of all to have a properly equipped place for working of a small work shop; secondly, there should be an adequate supply of parts (vacuum tubes, capacitors, and resistors).

The working area for the technicians should consist of a work bench (table) measuring about 800 x 1600 m, 700-800 mm off the floor, which it is desirable to have fitted with low edges on three sides and fitted with compartments and drawers to keep materials near the table, as well as a cabinet for keeping instruments and measuring devices and other small parts. This cabinet should be placed either directly above the bench (on the wall) at a slight distance above it, or else somewhat to the side. In addition to this cabinet, there should be some source of line voltage from a socket located above the bench or beside it. The work bench should be provided both with daylight and artificial illumination.

The control panel, connected to a source of industrial voltage,

should have supplies of 127 and 220 volts available. The wall voltage should be supplied at a power of 2.5 kVA. The following equipment should be kept in the instrument cabinet: a voltmeter (250 volts) and ammeter (10 and 20 amperes). There should be several sockets on the control panel: one common one for the entire panel, and two or three individual ones for smaller applications. /333 Each socket should be fitted with a separate fuse for a suitable current range. There should also be several jacks on the control panel.

In addition to the control panel and cabinet, there should also be an autotransformer (such as the laboratory autotransformer type "LATR"), a transformer which gives standard voltage for powering the filaments of vacuum tubes (2.5, 5, 6.3, 10 and 21 volts) at a current of 100-150 amperes, as well as a high-voltage transformer with stepwise regulation for testing the electrical continuity of insulation in windings after repairs, operating at a voltage of 2500 volts if the repairs have been made on a portable apparatus and at a voltage of 5000 volts if any other kind of repair has been made.

Other measuring instruments and devices which could be included in the list above are a vacuum tube (cathode) voltmeter, a bridge for measuring resistance and capacitance, a megameter for testing the resistance of insulation, and a resonance voltmeter with various ranges. A cathod-ray oscilloscope is also highly desirable.

Translated for the National Aeronautics and Space Administration by:
Aztec School of Languages, Inc.,
Research Translation Division (178)
Acton, Massachusetts
NASw-1692

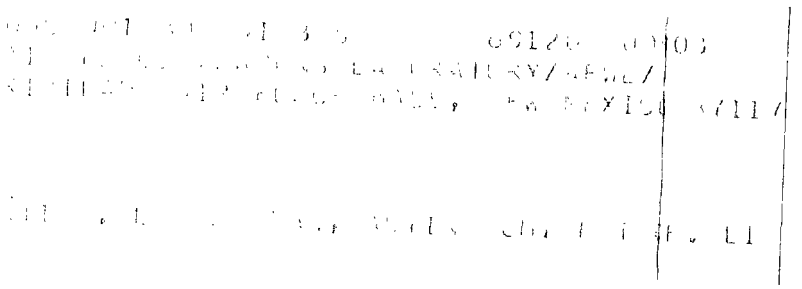
NASA-Langley, 1968 —— 5 F-523

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

OFFICIAL BUSINESS

FIRST CLASS MAIL

POSTAGE AND FEES PAID
NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION



If Undeliverable (Section 158
Postal Manual) Do Not Return

"The aeronautical and space activities of the United States shall be conducted so as to contribute . . . to the expansion of human knowledge of phenomena in the atmosphere and space. The Administration shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

NASA SCIENTIFIC AND TECHNICAL PUBLICATIONS

TECHNICAL REPORTS: Scientific and technical information considered important, complete, and a lasting contribution to existing knowledge.

TECHNICAL NOTES: Information less broad in scope but nevertheless of importance as a contribution to existing knowledge.

TECHNICAL MEMORANDUMS: Information receiving limited distribution because of preliminary data, security classification, or other reasons.

CONTRACTOR REPORTS: Scientific and technical information generated under a NASA contract or grant and considered an important contribution to existing knowledge.

TECHNICAL TRANSLATIONS: Information published in a foreign language considered to merit NASA distribution in English.

SPECIAL PUBLICATIONS: Information derived from or of value to NASA activities. Publications include conference proceedings, monographs, data compilations, handbooks, sourcebooks, and special bibliographies.

TECHNOLOGY UTILIZATION PUBLICATIONS: Information on technology used by NASA that may be of particular interest in commercial and other non-aerospace applications. Publications include Tech Briefs, Technology Utilization Reports and Notes, and Technology Surveys.

Details on the availability of these publications may be obtained from:

SCIENTIFIC AND TECHNICAL INFORMATION DIVISION

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Washington, D.C. 20546